DEVELOPMENT OF MULTIMODE WIRELESS SENSOR SYSTEM FOR REAL-TIME MONITORING

Session: BS. Fall 2023

Project Supervisor: Dr. Yumna Qureshi

Submitted By

Ali Hassan

Muhammad Awais

Department of Mechanical Engineering

Institute of Space Technology

Certification

This is to certify that **Ali Hassan**, **190501072** and **Muhammad Awais**, **190501005** have successfully completed the final project **Development of Multimode Wireless Sensor System for Real-Time Monitoring,** at the **Institute of Space Technology**, to fulfill the partial requirement of the degree **Bachelor of Science in Mechanical Engineering.**

Project Supervisor

Dr. Yumna Qureshi

Assistant Professor

Head of Department

Department of Mechanical Engineering, Institute of Space Technology

Development of Multimode Wireless Sensor System for Real-Time Monitoring

Sustainable Development Goals

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	**SDG 9** ✓	**Industry, Innovation, and Infrastructure**
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	**SDG 11** ✓	**Sustainable Cities and Communities**
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	✓
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	✓
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	✓
4	Familiarity of issues	Involve infrequently encountered issues	✓
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	✓
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	✓
7	Consequences	Have significant consequences in a range of contexts.	✓
8	Interdependence	Are high level problems including many component parts or sub-problems	✓
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	✓
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	✓
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	✓
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	✓
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	✓

Abstract

Structures and its parts are vulnerable to breakdown under operational conditions, which can lead to a loss of revenue, output, and, occasionally, even life. To prevent their catastrophic failure and high maintenance costs, extensive research has been done to build in situ sensors and monitoring systems. A mechanical structure's and/or system's numerous metrics can be monitored in real-time to assess health and condition in order to prolong service life.

The objectives for this project are to create an efficient wireless sensor system which can transmit data in real-time using multi functional materials for very accurate structural health monitoring. Additionally, the fourth industrial revolution, also known as industry 4.0, places a greater emphasis on enhancing equipment utilisation, decreasing operational costs, and raising worker productivity. To investigate the instantaneous functionality of a structure, a data processing system that can gather data over wireless media and perform appropriate monitoring operations is designed. As a multipurpose structure and sensor, a conductive fibre was created by electroless plating silver (Ag) on nylon-6 fibre. Utilising a universal testing machine (UTM) and a National Instruments DAQ system, the gauge factor was experimentally determined.

Following that, a wired sensor was transformed to a wireless sensor system utilising an ESP32 microcontroller and a number of amplifiers. By comparing the sensor's wireless response to its wired response, the sensor's wireless response was confirmed. The sensor was subsequently placed inside an epoxy composite sample for instantaneous deformation and damage detection under loading conditions after the results were confirmed.

A software system that collects data through a wireless medium, performs essential monitoring procedures, and displays results on a dashboard that can be seen on any device was then constructed in order to visualise the sensor's output in real-time. With the integration of wireless cloud computing, this study can offer a practical and affordable real-time health and status monitoring solution.

Keywords: Structural Health Monitoring, Wireless Sensor System, Multi-functional Materials, Electroless Plating, Conductive Fibers, Universal Testing Machine (UTM), ESP32 Microcontroller, Real-time Data Transmission

Undertaking

I certify that the project **Development of Multimode Wireless Sensor System for Real-Time Monitoring** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

Ali Hassan

190501072

Muhammad Awais

190501005

Acknowledgement

This study is devoted to our supportive families, inspiring teachers and supportive peers who have inspired and supported us throughout the course of this project.

Table of Contents

List of Tables

List of Figure

List of Acronyms

UTM	Universal Testing Machine
DAQ	Data Acquisition System
ELP	Electroless Plating
GF	Gauge Factor
NDT	Non-Destructive Testing
SHM	Structural Health Monitoring

Chapter 1: Introduction

1.1 Motivation

There is a category of materials called composite materials which are rapidly becoming famous in structural and technical applications because of their exceptional durability, lightweight nature, strong mechanical properties, cost-effectiveness, and ability to withstand various environmental conditions. They have greatly replaced traditional materials.[1] Nevertheless, they remain vulnerable to harm. In order to minimize the chances of material failure, it is crucial to thoroughly examine and consistently observe the operational characteristics of materials, particularly when they experience intense stress or are exposed to environmental factors like moisture, creep, or heat degradation. A technique known as Structural Health Monitoring also known as SHM is commonly employed to assess, monitor, and analyze the performance of materials and structures in real-world situations, with the primary goal of ensuring the safety and reliability. Due to the integration of monitoring systems and sensors, non-invasive methods for on-site material monitoring have transformed into invasive techniques. Numerous in-situ monitoring systems have been created to identify possible issues such as deformation, distribution of heat, cracking of fibers, corrosion, debonding/delamination, and intralaminar cracking. Non-destructive testing also known as NDT methods, such as ultrasonic detection, and X-rays have the capability to identify specific areas of damage without causing harm. However, these techniques often necessitate the dismantling of the structure and are unable to identify impending degradation.

The technique of acoustic emission which is commonly employed for the instantaneous observation of structural degradation. However, the interpretation of data necessitates an intricate and subjective methodology. It is essential to conduct research on the most up-to-date techniques for monitoring structural deformation in real-time. [5-6] It is usual practice to apply the usage of the SHM system to quantify the real-time funcationality of structures for the purpose of assuring their reliability and safety. While in operation, sensors are responsible for monitoring mechanical deformation, vibrations, and other critical factors. [7-8] These methods are suggested for crucial construction zones as they can identify and locate damage directly from its origin. By utilizing sensor network technologies that make use of lamb wave propagation, researchers have successfully determined the exact location of damage. Nevertheless, the utilization of these systems is limited due to their exorbitant price, large dimensions, and heavy weight, along with their intricate data processing and analysis. Building an accurate strain tracking and damage identification system is essential for keeping tabs on the mechanical behavior of buildings under a range of loading conditions. To fully understand behavior detection, it is important to use different sensor systems to differentiate between deformation and damage mechanisms in composite materials.

The rapid integration of sensor networks (WSNs) in the domain of SHM has been crucial in safeguarding the structural integrity and security of infrastructure in civil engineering field. Wireless Sensor Networks (WSNs) offer numerous benefits, such as the ability to remotely monitor systems, collect data efficiently, and achieve cost-effectiveness. They provide a more affordable option compared to conventional wired systems as they eliminate the requirement for extensive cabling, resulting in reduced expenses for installation and upkeep. Moreover, Wireless Sensor Networks (WSNs) allow for the ongoing and independent gathering of data, making it easier to oversee the performance of structures in real-time and quickly detect any irregularities.[10] The utilization of real-time data collection has the ability to enhance the precision of structural assessments, accelerate preventive maintenance efforts, and decrease the likelihood of severe structural breakdowns.[11] Wireless Sensor Networks (WSNs) have the capability to remotely monitor various systems, eliminating the requirement for physical presence on-site during monitoring activities. This feature also allows for greater flexibility in retrieving data [12].

1.2 Objective

The reason for conducting this project is to design and subsequently implement a Multimode wireless sensor system capable of providing instantaneous monitoring of diverse parameters across a range of settings. The system under consideration consists of a wireless sensor network that can operate in various modes, including Bluetooth and Wi-Fi, thus offering flexibility with respect to communication and transmission of data.

The proposed system would be created with scalability and adaptability in mind, making it appropriate for use in a number of settings such as industrial monitoring, environmental monitoring, and healthcare applications. It will gather data on numerous aspects such as temperature, humidity, pressure, and motion using modern sensor technologies. The information gathered will be wirelessly transferred to a central monitoring system for analysis and interpretation.

The proposed project entails the creation and implementation of wireless sensor nodes, which requires a thorough assessment and choice of suitable sensors, microcontrollers, and wirelesscommunication modules. The proposed system is designed to incorporate a centralized monitoring facility that will receive, analyze, and display the data collected by the sensor in real-time. The development of the central monitoring system will involve the utilization of sophisticated software technologies.

The objective of this investigation is to establish a dependable and effective wireless sensor networkthat can be utilized for instantaneous monitoring of diverse parameters in varying settings. The proposed project entails a comprehensive evaluation and validation of the system utilizing diverse testing techniques such as performance, reliability, and environmental testing, with the aim of ascertaining that the system conforms to the prescribed standards and specifications.

The primary objective of the initiative concerning the Multimode Wireless Sensor System for Real-time Monitoring is to create a novel and adaptable wireless sensor system which is capable of being deployed in diverse settings and for numerous purposes. The proposed undertaking is expected to make a noteworthy contribution to the advancement of sensing technologies.

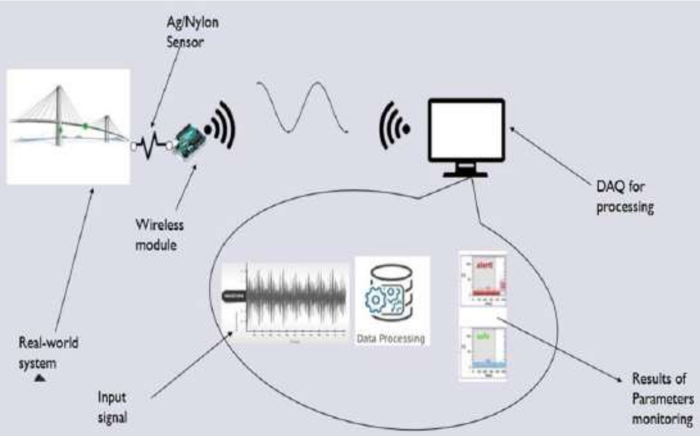

Figure 1: Proposed Schematic of Wireless Sensor System

Chapter 2: Literature Survey

Over the past years, the area of SHM has experienced notable advancements due to the imperative requirement for ongoing surveillance and upkeep of deteriorating civil infrastructure. The formulation and execution of efficient Structural Health Monitoring (SHM) tactics possess the capability to significantly enhance the serviceable lifespan of constructions, enhance the safety of the public, and curtail expenses related to restoration.[13] SHMis comparable to the human body in that both systems entail monitoring the health of a complex, interdependent structure. Structural Health Monitoring (SHM) employs various technologies and sensors to identify potential structural anomalies, analogous to how medical practitioners utilize imaging and medical tests to diagnose health conditions in the human body. Early detection of issuesin the human body can result in successful treatment and recovery. Similarly, in Structural Health Monitoring (SHM), timely identification of problems in a structure can facilitate effective restoration,thereby prolonging the structure's lifespan and averting future, more costly repairs.[14]

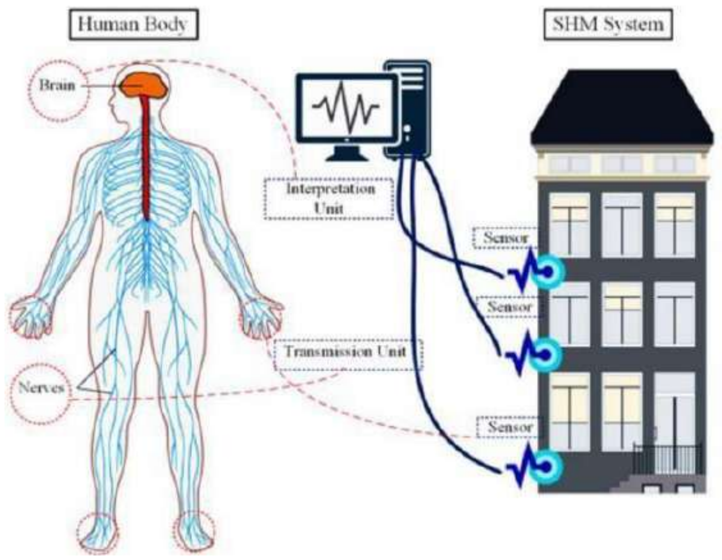

Figure 2: Analogy between human body and SHM system

Structural health monitoring (SHM) has made great strides thanks to the integration of cutting-edge sensors and signal processing techniques. The progress of sensor technology, which provides complete insights into the state of enormous structures, has enabled the employment of distributed sensor mesh for monitoring of structural health.

Furthermore, advances in signal processing have made it possible to detect and monitor probable structural breakdowns in real time. [15]

Figure 3: Wireless sensor for SHM

The SHM has seen a surge in study and development pertaining to composite and multifunctional materials, owing to their distinctive characteristics and potential for integration with sensing and actuation technologies. Composites, consisting of multiple dissimilar materials, present a multitude of benefits when compared to traditional structural materials. They exhibit enhanced strength, durability, and environmental resistance. Furthermore, the incorporation of fibres or particles into the composite matrix can impart unique sensing and actuationcharacteristics.[16], [17] Considerable investigation has been carried out regarding the incorporation of sensors within composite structures. The integration of carbon nanotubes (CNTs) into compositeshas yielded multifunctional materials that possess both structural reinforcement and strain sensing capabilities. Carbon nanotubes (CNTs) are recognized for their piezo resistive characteristics, which make them suitable for use as strain sensors in composite materials. Carbon microfiber (CM) sensorshave been integrated with composites to develop self-sensing materials that can instantaneously detect tension and strain.[18], [19]

Composites not only offer unique sensing capabilities, but also actuation qualities. In reaction to an external stimulus, such as heat, "shape memory polymers" (SMPs) may be employed to develop multifunctional materials with form-changing capabilities. form memory composites are a kind of material having sensing and actuation capabilities that may change form in response to an external input.[20], [21]

In addition, studies on the self-repairing properties of multifunctional materials have been done. Self-healing materials have the capacity to identify and fix damage without the need for human involvement. Several improvements in self-healing materials have occurred, including the incorporation of shape memory polymers and encapsulated healing agents. The incorporation of self-repairing qualities into composite materials can result in a longer operating life and shorter maintenance intervals.

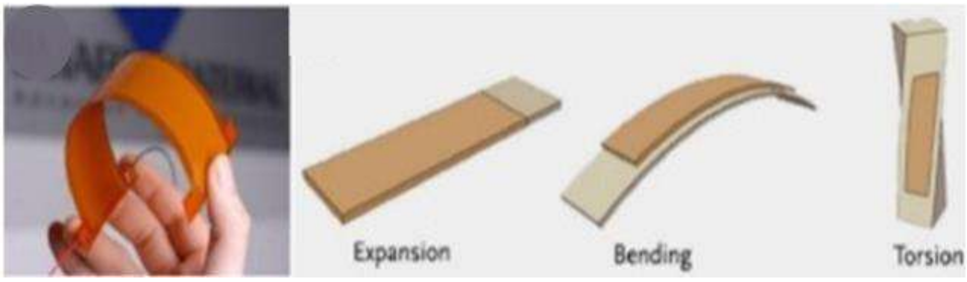

Figure 4: Multifunctional material as used in a sensor in structural health monitoring

Despite the advantageous properties of composite and multifunctional materials for SHM, a number of obstacles remain. For instance, the development of dependable and precise sensing and actuation capabilities for composites remains an active area of study. In addition, the costly cost of these materials can restrict their widespread application in civil infrastructure. [22]

SHM has the capability to evolve thanks to the usage of smart materials and composites, which can create self-sensing, self-actuating, and self-repairing structures.[23] To develop dependable and affordable civil infrastructure solutions that can be broadly used, further research is required.

Due to its capacity to gather data in real-time and ease of implementation, Wireless Sensor Networks (WSNs) have significantly increased in demand in the SHM field. Because of its capacity to gather and transmit real-time data on a variety of factors, including as temperature, humidity, pressure, and strain, Wireless Sensor Networks (WSNs) are advantageous for the use of SHM.[24] The aforementioned data can be utilized for real-time detection of alterations in system behavior, thereby facilitating preemptive maintenance and averting structural malfunctions. Wireless Sensor Networks (WSNs) have the capacity to monitor multiple locations on a given structure concurrently, thus offering a comprehensive and precise depiction of the structural health status.[25].

Wireless Sensor Networks (WSNs) present a multitude of advantages in the realm of Structural Health Monitoring (SHM); nevertheless, they do possess certain limitations. The precision of data obtained by Wireless Sensor Networks (WSNs) may be jeopardized by interference emanating from diverse electronic devices. The practicality of Wireless Sensor Networks (WSNs) in expansive structures may be constrained by their limited range. Furthermore, the deployment and maintenance of Wireless Sensor Networks (WSNs) may result in substantial expenses, thereby constraining their suitability for specific applications.[26]

Current studies are examining the capabilities and possible improvements of "Wireless Sensor Networks (WSNs)" in "Structural Health Monitoring (SHM)", which is a promising field of research. The development of machine learning algorithms that can analyze data gathered by wireless sensor networks (WSNs), spot abnormalities suggestive of structural degradation, and enable more precise and effective decision-making is currently being worked on [29]. Future improvements in wireless communication technologies are predicted to increase the breadth and precision of wireless sensor networks (WSNs).

Because they make it possible to collect data in real-time and monitor different areas of a structure, Wireless Sensor Networks (WSNs) are widely acknowledged as an effective strategy in structural health monitoring (SHM). while still case

Despite the fact that studies have some limits, their successful application and promise for future use provide reason for their application. Additional research and development projects are projected to increase these constructions' functions and reduce their limitations, which will increase their significance in ensuring the security and dependability of buildings.[30]

Due to its ability to deliver accurate and timely data on a structure's state, in-situ sensors have become increasingly important in structural health monitoring (SHM) systems. Because in-situ sensors may provide high frequency, real-time data on the structural performance, their use in SHM is considered to be beneficial. The information may be used to instantly spot any changes in a structure's behavior. This makes preventive maintenance easier and helps prevent structural collapse. Utilizing in-situ sensors makes it possible to quantify a variety of characteristics, such as vibration, displacement, temperature, and strain, among others, allowing for a thorough assessment of structural soundness.[3]

There are various advantages of using in-situ sensors in the context of SHM. It is crucial to understand that these sensors are subject to certain limitations. The deployment, maintenance, and operation of sensors come at a high cost, and their dependability is susceptible to changes in environmental factors. The sensors have a data drift or noise vulnerability, which makes measurements less accurate. Due to possible problems gaining access to the structure, installing sensors may be difficult or prohibitive in some situations.[31] In the field of SHM, recent research has mainly examined the possible improvements and capabilities of in-situ sensors. Creating machine-learning algorithms is the goal ability to analyse data obtained from in-situ sensors, spot abnormalities that might indicate structural degradation, and provide more precise and effective decision-making. Future improvements in sensor technology are anticipated to improve the accuracy and range of in-situ sensors. [32]

Due to its capacity to provide exact and immediate information on the structural integrity of a specific building, in-situ sensors are an important instrument in "structural health monitoring (SHM)". The effective use of case studies and encouraging prospects promote their use despite their drawbacks. It is anticipated that ongoing research and development projects will improve the capabilities and lessen the restrictions of the aforementioned structures, increasing their significance in maintaining structural safety and dependability. Silver-coated nylon wire is widely used in SHM due to its excellent electrical conductivity, flexibility, toughness, and affordability. Numerous studies have been done to determine whether using silver-coated nylon wire as a sensing element in applications for structural health monitoring (SHM) is feasible.[2]

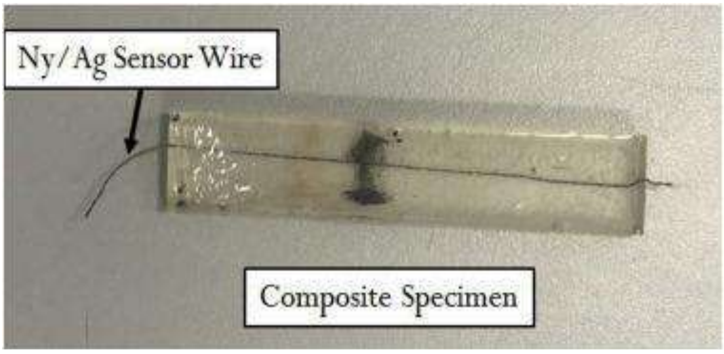

Figure 5: Silver coated Nylon yarn sensor for “Structural health monitoring”.

Damage detection in composite and steel structures might be aided by using nylon thread coated with silver. For uses like structural health monitoring (SHM), it provides a lot of benefits beyond just sensing. The wire's flexibility makes it easy to install on various structural components, and its lifespan and resistance to corrosion make it suitable for use in adverse weather conditions. Due to its exceptional sensitivity, flexibility, durability, corrosion resistance, and cost-effectiveness, silver-coated nylon wire for SHM is well suited for the continuous surveillance of civil infrastructure. The practicality of using silver-coated nylon wire in other structural health monitoring (SHM) applications may be investigated in later research, which might also improve the effectiveness of the wire for structural components. [7]

The application of cloud computing in the area of structural health monitoring (SHM) has been the subject of several academic studies. A cloud dependent SHM system for suspension bridges was suggested by Naraharisetty et al. in 2023. The technology used wireless sensors to collect information from the bridge, which was then sent to a cloud server for quick analysis. A cloud-based Structural Health Monitoring (SHM) system is effective in accurately identifying and diagnosing structural damage in bridges, as demonstrated by the study the authors conducted.

A cloud connected SHM system for a bridge used for high-speed train was previously developed by Ding et al. (2017). Embedded sensors were used to monitor the bridge's structural soundness, and they sent the collected data to a cloud server for quick analysis. According to the authors' study, the SHM, which makes use of the cloud,cNew innovative technology is able to deliver accurate and fast notifications about probable structural abnormalities.

Zhao et al. (2015) reviewed the most recent advancements made in cloud dependent SHM systems. scalable and cost-effective cloud-based SHM technologies were highlighted as being of paramount importance in the research. The study's authors also addressed some of the limitations of cloud-based structural health monitoring (SHM) systems, such as data privacy and security concerns.

Chapter 3: Methodology

3.1. Silver Coated Nylon Sensor preparation.

3.1.1. Materials Used

The table presented below enumerates the materials used in the electrodes plating process of silver particles onto Nylon, as well as in the production of epoxy samples.

Sr#	Material	Concentration	Mass or volume
1	Silver Nitrate($AgNO_3$)	0.0919 mol/litre	0.3125 g
2	Sodium Hydroxide (NaOH)	0.25 mol/litre	0.2 g
3	Ethanol	95 %	20 ml
4	Aqueous Ammonia (NH_4OH)	PH = 14	50 ml
5	Nylon (800d)		50 cm
6	Razeen LR 1100 unmodified liquid epoxy		40 ml
7	Razeen LR 1100 hardener		20 ml

Table 1: Material used for Ag/Nylon Sensor preparation.

3.1.2. Procedure

Nylon yarn was meant to be used in this project which showed good mechanical properties and flexibility, but its electrical conductivity was low. Therefore, its conductivity had to be enhanced before it could be used in a strain sensing device. Researchers have discovered that adding nanofillers to a fiber can increase its conductivity, but only to a certain extent. Add too much and the mechanical performance may suffer. Using an effective electroless plating process, silver metal nano scale particles were deposited on the surface of each strand of the nylon thread in a continuous and uniform manner on a very small scale to solve this problem. This method can be applied to complex surfaces and shapes.The procedure's stages are:

1. Nylon yarn was washed with 20 ml ethanol for 10 minutes, and then washed with distilled water three times and dried in room temperature.

2. In a beaker, 20 ml distilled water, 0.3125g of AgNO3 and 0.2g of NaOH were mixed. It immediately created brown precipitates of silver hydroxide. The solution was heated and stirred at 130 C for 2 hours.

3. Solution cooled down, nylon yarn was added into the solution and again heated at 130 C for 2 hours. It created a layer of silver oxide on the surface of nylon yarn. When silver nitrate is added to an alkali solution, it creates a hydrated form of silver (Ag+). This form of silver then turns into silver oxide (Ag2O) through a reaction with OH- ions. This reaction produces a dark cream solution due to the formation of a lot of silver oxide. If the temperature is increased to 130°C in a strong alkali environment, the silver oxide dissociates into Ag+ ions that bond with hydroxyl and carboxylate groups on the fibre surfaces. The solution turns colourless.

4. The solution was treated with aqueous ammonia environment and again heated at 130 C to reduce the silver oxide layer into silver metal.

5. It formed an even coating of silver metal nanoparticles on the surface of nylon yarn.

3.1.3. Chemical Reaction:

When silver nitrate is mixed with sodium hydroxide, silver oxide, sodium nitrate and water are produced.

$$2AgNO3 + 2NaOH \longrightarrow Ag2O(s) + 2NaNO3 +$$

$$H2O(l)Ag2O(s) \longrightarrow 2Ag^{+} + O^{2-}$$

The alkaline treatment of polyester results in the production of ethylene glycol, which is subjected to oxidation, yielding electrons. This, in turn, reduces the silver ions to form silver nanoparticles, giving rise to a clear solution.

H- [-O-CH2-CH2-O-CO-(C6 H4)-CO-]n -OH + 2NaO ⟶ *HOCH2CH2OH + H2O +*

H-[-O-CH2-CH2-O-CO-(C6 H4)-CO-]n-1 -OH + NaO-CO-(C6 H)-CO-ONa

HOCH2CH2OH ⟶ *CH3CHO + H2O*

CH3CHO + 3OH⁻ ⟶ *CH3COO⁻ + 2H2O+2e⁻*

$Ag^{+} + e^{-} \longrightarrow Ag^{0}$

The silver nanoparticles that are produced stick to the surface of the polyester fabric due to physical interlocking, which is caused by the rough surface that was created by the hydrolysis of polyester in an alkali solution.

The process for creating a silver layer on nylon fiber is described by the equations.

Ag2O(s) + 4NH3 (aq) + 2NaNO3 (aq) + H2O ⟶ *2Ag(NH3)NO3(aq) + 2NaOH(aq)*

2Ag(NH3)NO3(aq) + CH3CHO ⟶ *+2 Ag⁰ + CH3CHOOH +4NH3 + HNO3*

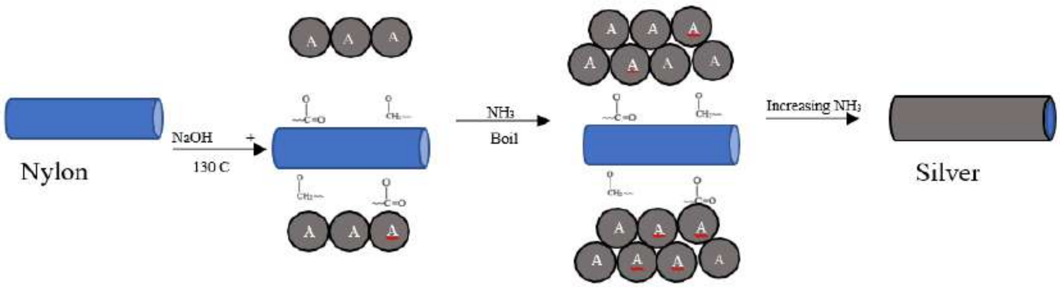

Figure 6: Schematic diagram of Chemical reaction

Figure 7: Sample after being Coated

3.1.4. Epoxy Sample Preparation

The first step was to prepare a CAD model for the mold and get it 3d printed.The model was created using PTC Creo Parametric 5.0. The epoxy specimen was made on ASTM d-638 standard. The mold was designed likewise

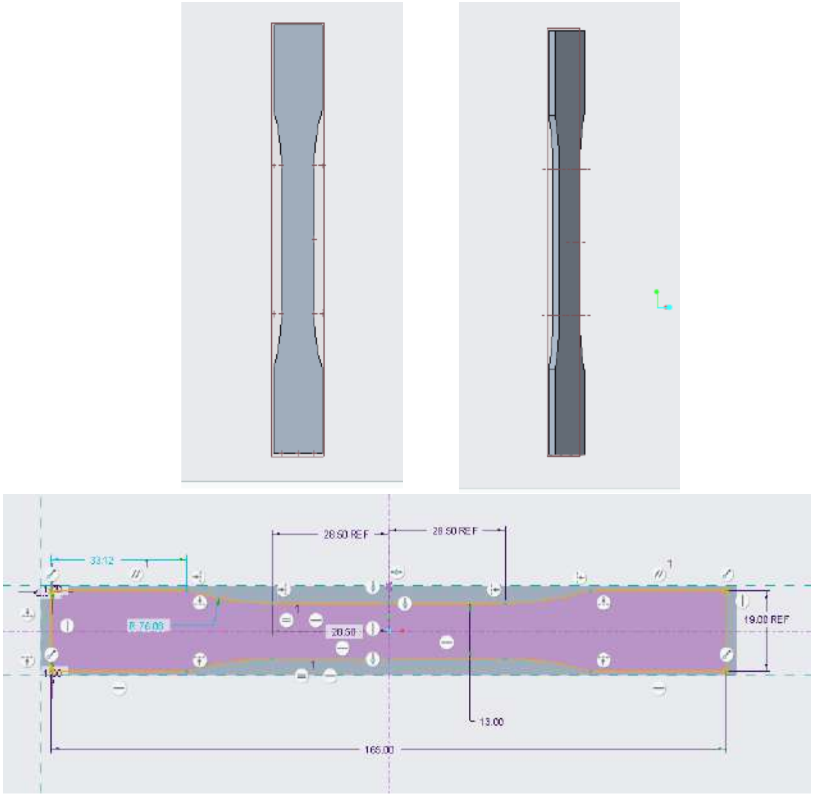

Figure 8: CAD model of the mold

Figure 9: Preparation of the Epoxy Matrix

3.1.4.1. Procedure for making epoxy specimens.

1. Design the CAD model of the mold in Creo Parametric 5.0
2. 3d print the Model.
3. Cure the 3d printed mold.
4. Now put 40ml of epoxy in a beaker.
5. Now add 20ml of hardener in the same beaker.
6. Stir the mixture thoroughly and try to avoid air bubbles formation.
7. Place Sensor wire inside the mold and pour the mixture on it.
8. Let the specimen cure for 8 hours at room temperature.
9. Extract the specimen from the mold.

Figure 10: Epoxy Preparation chemicals

3.1.4.2. Procedure for Gage Factor Testing

1. Design a voltage divider circuit for measuring voltage drop across the sensor.
2. Using the voltage drop and current, find the resistance.
3. Use NI Data Acquisition system NI-1008 with NI 6251 DAQ card.
4. Connect the circuits according to the given diagram.
5. Now place the sensor on UTM machine and start the testing.
6. Take loading and strain readings from the UTM machine.
7. Take the voltage readings from the DAQ.

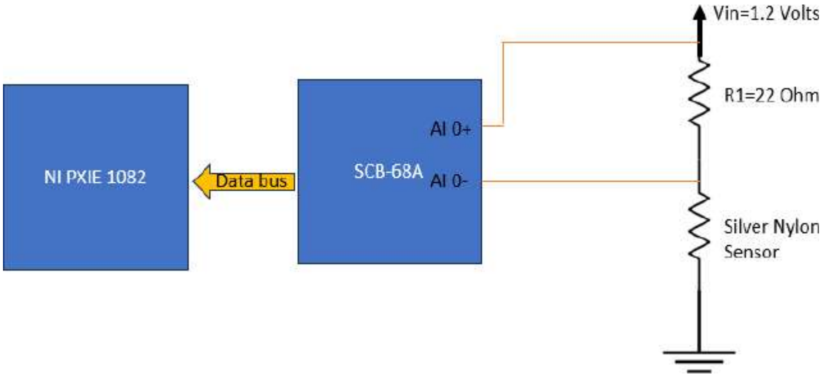

Figure 11: Schematic of the Electrical Circuit for Wired sensor

Figure 12: NI Data Acquisition System

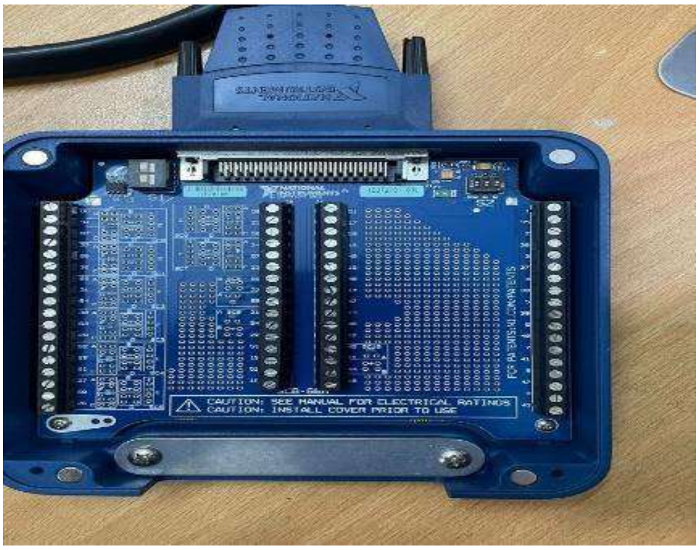

Figure 13: NI SCB-68A

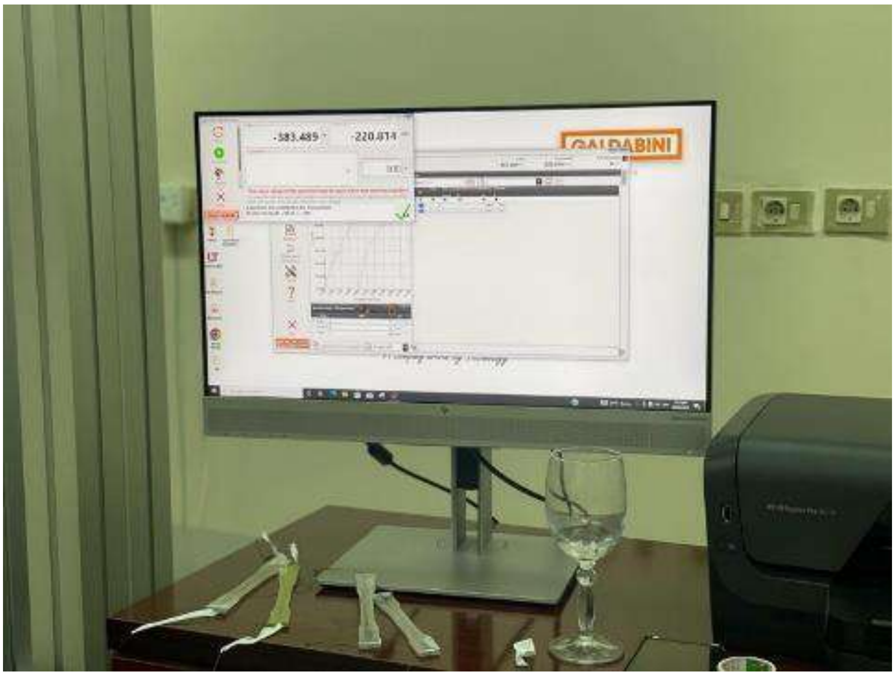

Figure 14: Display for UTM Machine

Figure 15: UTM Machine

Figure 17: Electrical circuit and mounted near the UTM machine

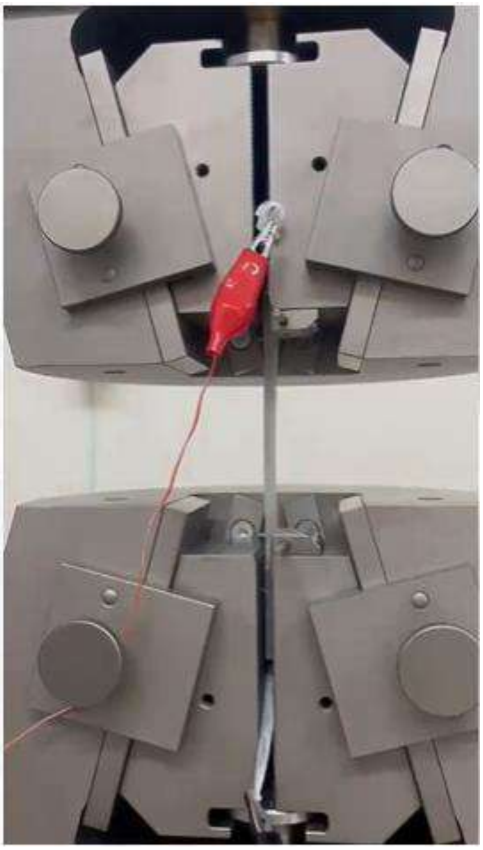

Figure 16: Specimen Fixed with in the jaws of UTM.

3.2. Wireless Module Preparation for Sensor System

Using ESP32 and ADS1115 analog to digital converter, Wireless module was developed. Connect the ESP 32 and ADS1115 using the schematic shown below.

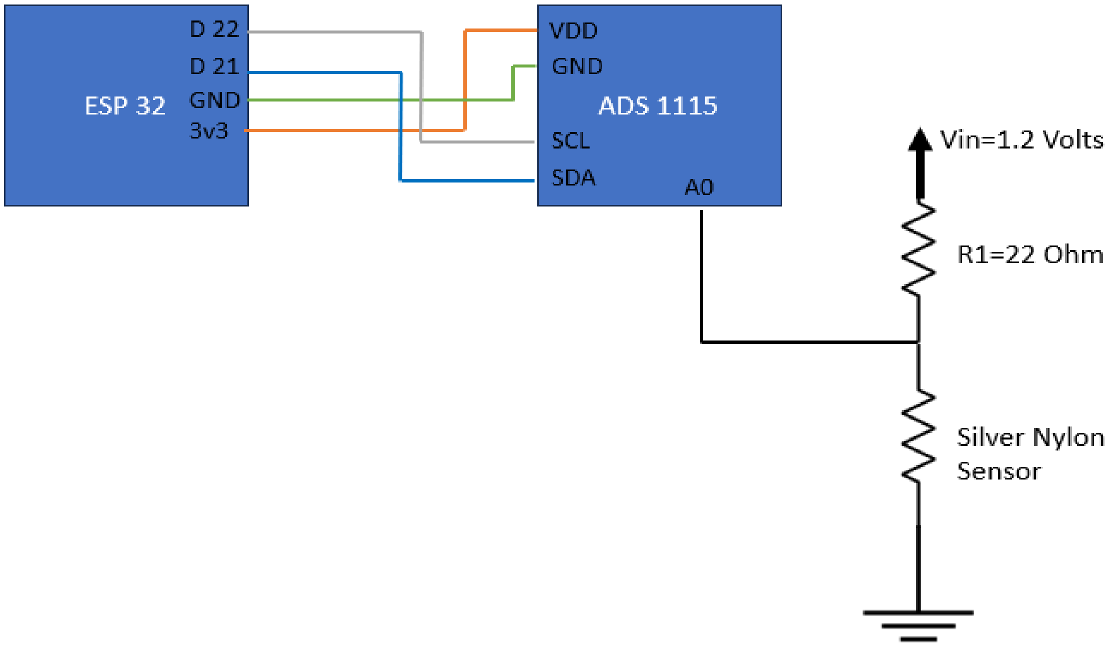

Figure 18: Schematic showing the electrical circuit of wireless module.

With reference to Appendix A: Arduino code, the explanation of Arduino code is as follows:

- This Arduino code allows you to read voltage values from a sensor using an ADS1115 analog-to-digital converter (ADC). The data is then sent to a Firebase Realtime Database with the help of the FirebaseESP32 library. To accomplish this, we need to include certain libraries: "Wire.h" for I2C communication, "Adafruit_ADS1X15.h" for the ADS1115 ADC, and "FirebaseESP32.h" for Firebase integration.
- In the code, we create an instance of the Adafruit_ADS1115 class called "ads" to represent the ADS1115 ADC. The ADS1115 is a 16-bit ADC that comes with four input channels. The I2C address of the ADS1115 is set to the default value of 0x48. To store the voltage drop calculated from the ADC reading, we declare a float variable called "voltageDrop."
- To configure Firebase, we use constants: "FIREBASE_HOST" represents the URL of the Firebase Realtime Database, and "FIREBASE_AUTH" represents the

authentication token. We also provide the Wi-Fi credentials (WIFI_SSID and WIFI_PASSWORD) for connecting to the network.

- In the setup() function: We start serial communication at a baud rate of 115200. The "ads" object is initialized with the I2C address of the ADS1115. We establish the Wi-Fi connection and print the IP address to the serial monitor. Firebase is initialized, and Wi-Fi reconnection is enabled. We set the database read timeout to 1 minute and the write size limit to "tiny" (1 second). Serial messages are used to indicate a successful connection.
- In the loop() function: We read the ADC value of channel 0 using "ads.readADC_SingleEnded(0)."The voltage is calculated from the ADC value using the formula "voltage = adc0 * 0.1875." The voltage drop is then calculated by dividing the voltage by 1000 and stored in the variable "Voltage Drop"
- The code calculates the current (i) and resistance (r) based on the voltage drop using Ohm's Law. The voltage drop and resistance values are printed to the serial monitor. To store the resistance value (r), we use a FirebaseJson object called "json" and save it under the "/Reading1" path. Finally, the json object is updated.in the Firebase Realtime Database under the "/Sensor" node. There is a 1-second delay before the loop repeats

3.3. Dashboard

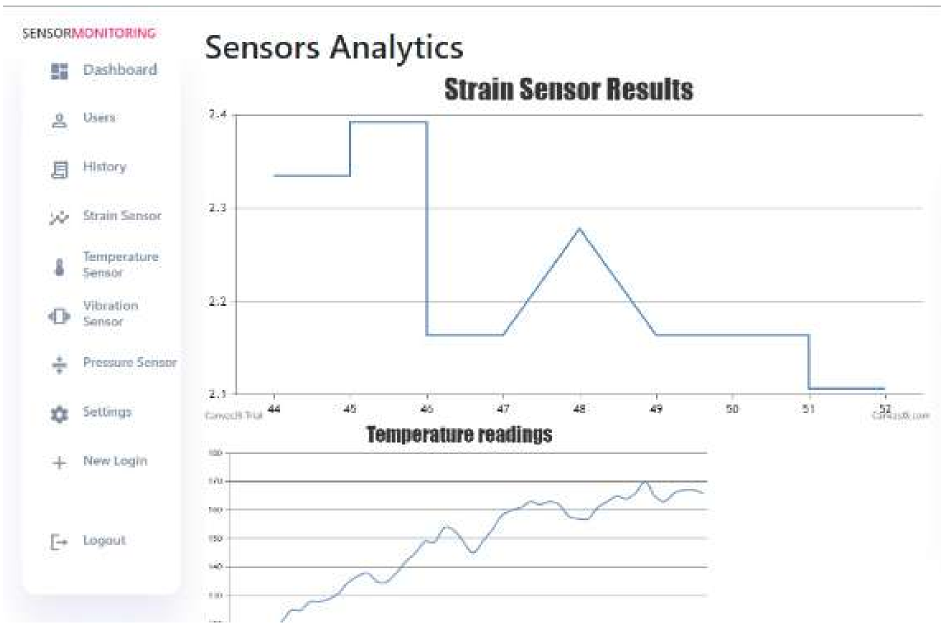

Figure 19: Live Dashboard Showing Response

Chapter 4: Results and Discussion

4.1.Sensor Characterization

The process of characterizing the sensor is segmented into five distinct sections.

1. SEM Characterization
2. EDS Characterization
3. XRD Characterization
4. Electrical Resistivity
5. Gage Factor

4.1.1. SEM Characterization

The Mira3 TESCAN system was employed for the purpose of scanning electron microscopy characterization.

1. Sample preparation: The first step involved the preparation of a sample of nylon fibre that was coated with silver, which was subsequently subjected to imaging using scanning electron microscopy (SEM). The sample was divided into small pieces and attached to a conductive surface, such as carbon tape or metallic stubs. In order to prevent contamination, it is essential to meticulously clean and desiccate the sample before imaging.

2. Imaging: After the completion of the preparation of the sample, it was introduced into the chamber of the scanning electron microscope (SEM) and underwent imaging procedures. Utilization of an electron beam to examine the surface of a specimen characterises Scanning Electron Microscopy (SEM), which generates images of outstanding resolution. In order to attain the highest possible standard of image quality, it is essential to optimise the imaging conditions, including the accelerating voltage, beam current, and working distance, in accordance with the particular sample under investigation.

3. Analysis: Following acquisition, the images were subjected to analysis to examine the surface morphology and microstructure of the nylon fibre that had been treated with silver. The utilisation of scanning electron microscopy (SEM) images provides valuable information regarding the surface morphology, particle dimensions, and dispersion of the silver coating, as well as the overall structural integrity of the fibre.

4. SEM testing: The utilisation of SEM testing on silver coated nylon fibre can yield significant findings regarding the material's surface morphology and microstructure. This can contribute to the enhancement of our comprehension of the material's properties and possible applications.

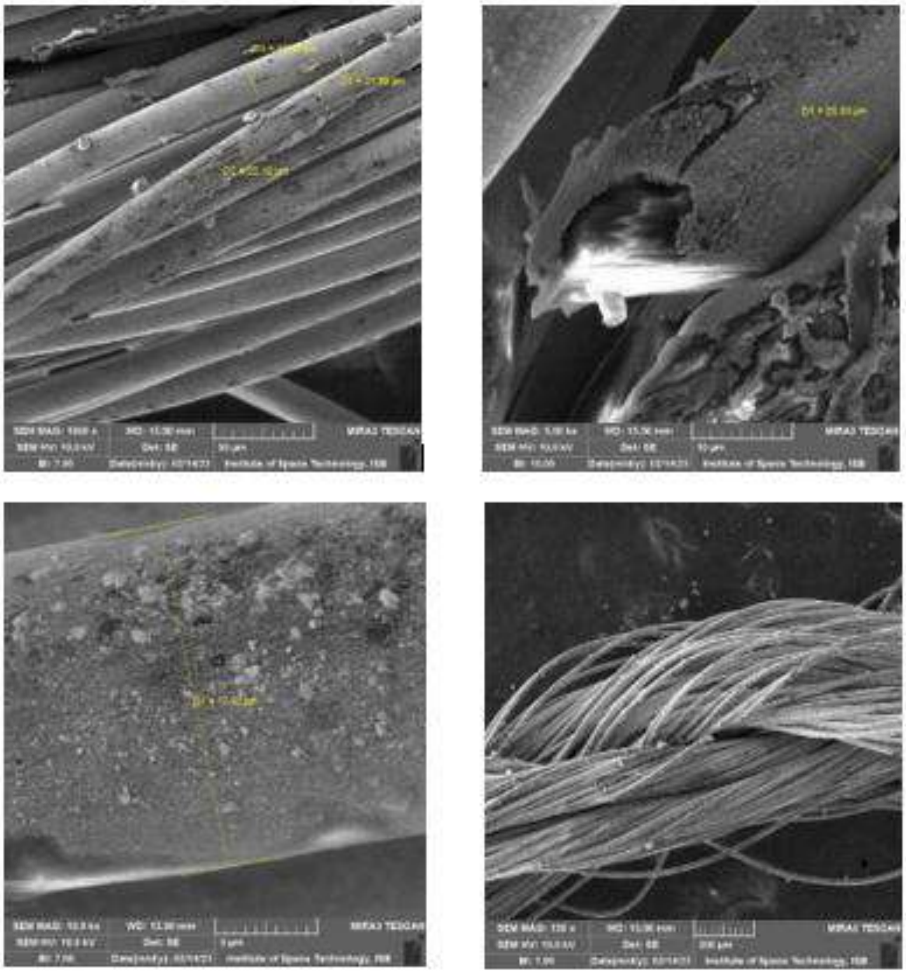

Figure 20: SEM imaging of Silver Coated Nylon Yarn

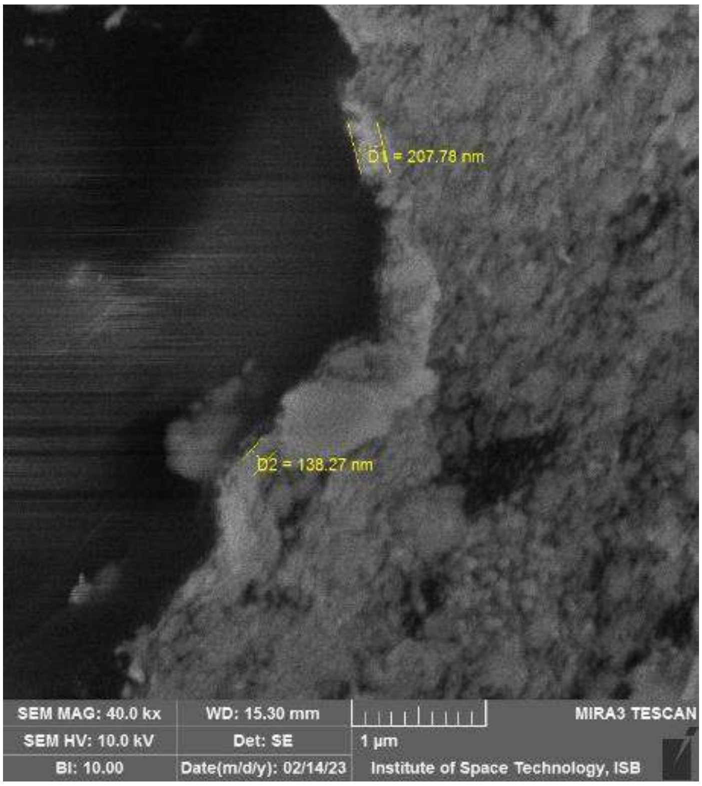

Figure 21: SEM image showing coating thickness on single strand

The figures depict the visual representations acquired through employment of the MIRA3 TESCAN system. The presented data unambiguously demonstrate the homogeneous distribution of silver metal deposition on individual strands of the Nylon Yarn. A limited number of instances were noted in which the yarn's coating had incurred damage. The damaged patches exhibited a range in length spanning from 20μm to 45μm. The damage that transpired during the clamping of the yarn with tweezers was attributed to the incident.

The measurement of the thickness of the coating yielded a value of 207.76 nanometres. The ratio of coating thickness to strand thickness has been determined to be 2% through calculation.

4.1.2. EDS Characterization

Mira3 TESCAN system was used for EDS Characterization EDS characterization is an X-ray spectroscopy technique that identifies the chemical composition of a sample by detecting the unique X-rays emitted when it is bombarded with high-energy electrons or X-rays. It is commonly used in materials science, geology, and biological sciences to analyze sample composition, often in conjunction with other methods such as "scanning electron microscopy (SEM)".

The results indicated that the sample contained 96.81 weight percentage of Silver element and 3.19 weight percent of Carbon element.

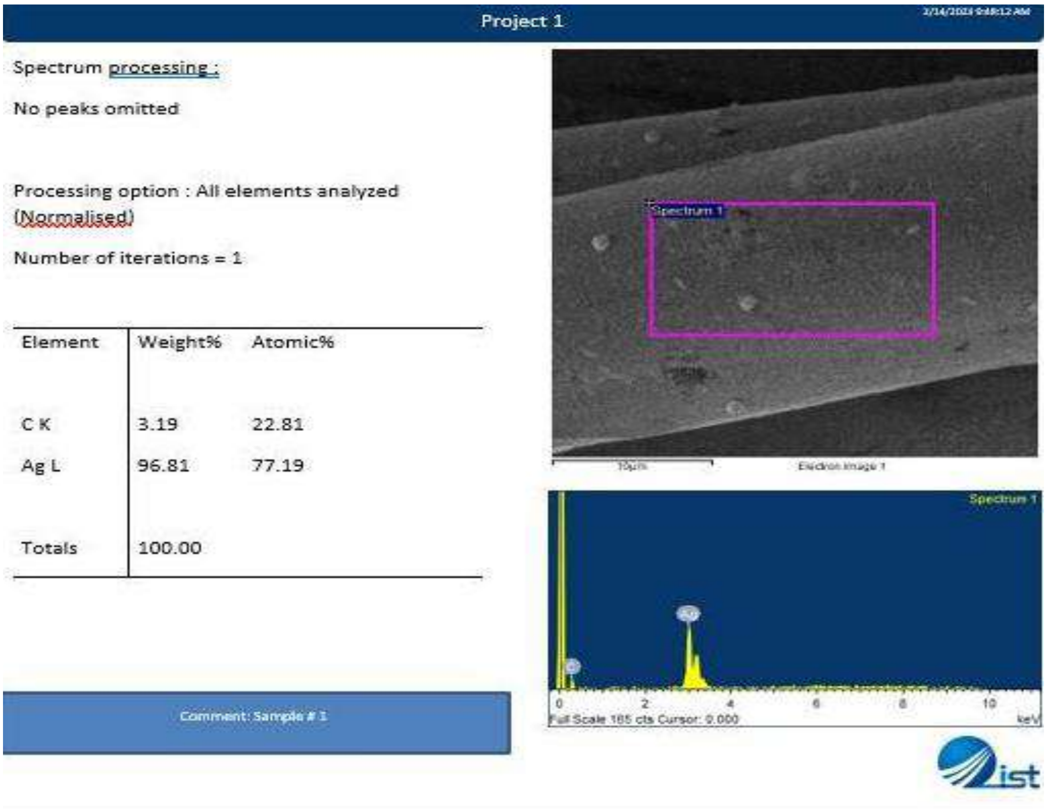

Figure 22: EDS Characterization Images of the Sample

4.1.3. XRD Characterization

The utilisation of X-ray diffraction (XRD) technique is employed to investigate the crystallographic characteristics of a specified substance. The methodology entails the utilisation of X-rays to investigate the structure of the material, followed by the measurement of the diffraction pattern that arises from the interaction. The utilisation of it is widely observed in the domains of materials science, chemistry, and solid-state physics to investigate various material categories, thereby providing essential perspectives into their respective characteristics.

The following table exhibits the technical specifications related to the X-ray diffraction (XRD) examination carried out on the sample.

Test Data	
Temperature	20±1 °C
Humidity	23 ± 1 %
Test Name	XRD Analysis
Test Purpose	Phase analysis of specimen
Instrument used	X-ray Diffractometer (D8 Advance)
Scanning range (2Θ)	05°- 80°
Results	The XRD scan of the sample indicate that the largest peak observed at 38.2° indicatesthe presence of Silver.

Table 2: Technical Details of XRD Testing

The figure displaying the X-ray diffraction (XRD) pattern presents proof of the availability of silver on the exterior of the sample. This is supported by the observation of a well-defined peak at an angle of 38.1 degrees.

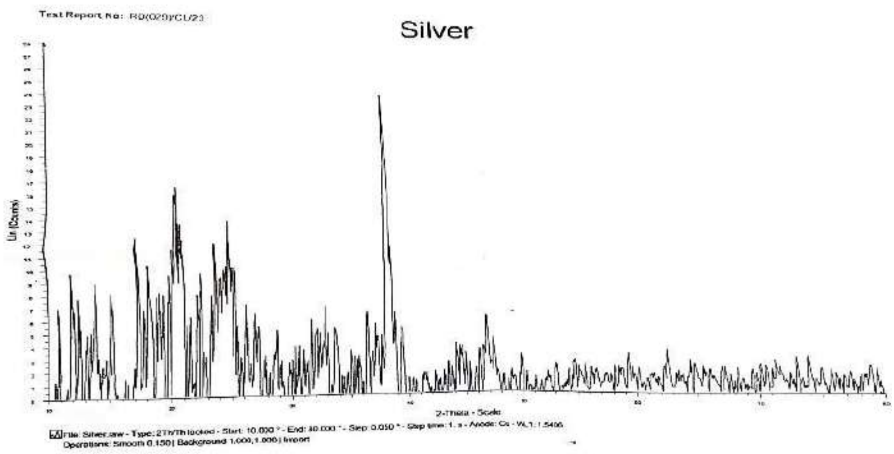

Figure 23: XRD Characterization graph of the sample

4.1.4. Electrical Resistivity

In order to determine the resistance of a conductive sensor that has been coated with silver-coated nylon, it is imperative to utilise a measuring instrument, such as a multimeter, that possesses the ability to measure resistance.

It is crucial to guarantee that the sensor is not situated in close proximity to any conductive materials or surfaces that could potentially hinder the precision of the measurement.

1. Proceed to attach the leads of the multimeter to the two terminals of the sensor.
2. Configure the multimeter to the resistance measurement mode and calibrate the range to a suitable magnitude.
3. Apply a small amount of pressure or force to the sensor to ensure that it is making good contact with the multimeter leads.
4. Read the resistance value displayed on the multimeter.
5. If necessary, repeat the measurement multiple times to ensure consistency and accuracy.

Resistance from the multimeter was found to be 40.5 Ohm/foot.

4.2. Wired Sensor testing

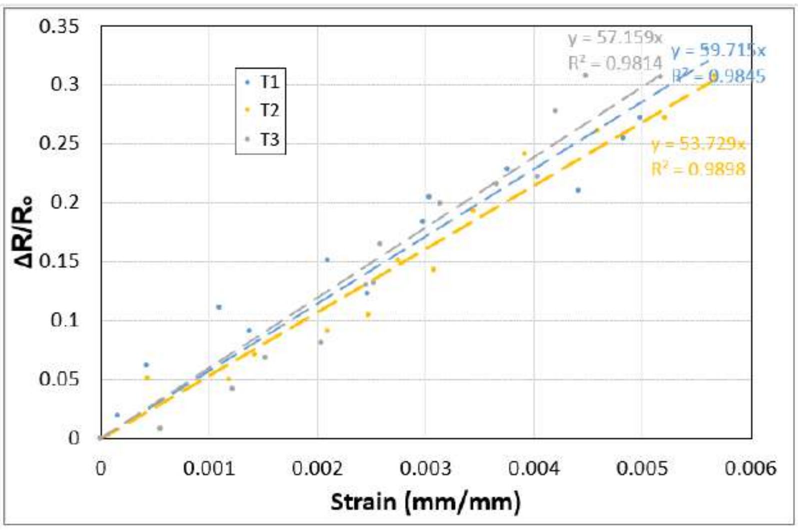

Figure 24: Gage Factor of Wired Sensor

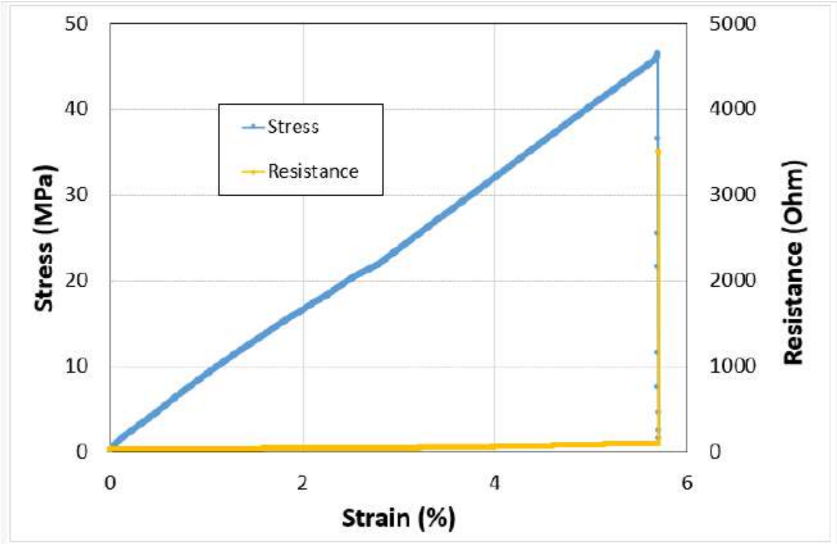

Figure 25: Strain Monitoring Response of Wired Sensor

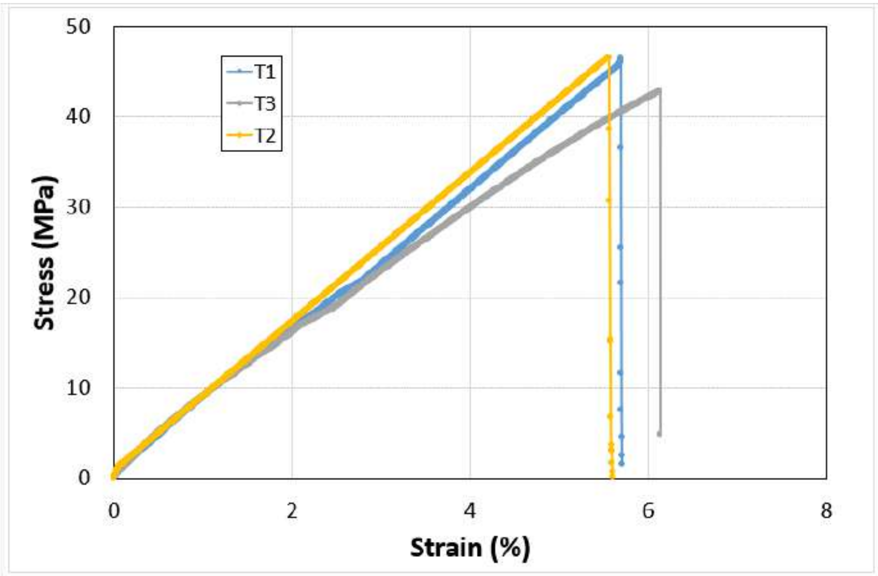

Figure 26: Reproducibility of Mechanical Response of Wired Sensor

The figure 24 shows the gage factor of the wired sample. It indicates that the wired samples have an average gage factor of 56.867. It indicates that the sensor is highly responsive to minute strains.

The figure 25 shows Strain monitoring response of the wired sample, It indicates that for the wired sample the resistance increased with increase in strain and the resistance peaked to the open circuit value at the point of rupture.

The figure 26 shows the reproducible mechanical behavior of the wired sample. It indicates that the wired samples were mechanically consistent with each other. The maximum stress sustained before failure was close to 45Mpa.

4.3. Wireless Sensor Testing

The figure 27 shows the gage factor of the wireless sample. It indicates that the wireless samples have an average gage factor of 56.305. It indicates that the sensor is highly responsive to minute strains.

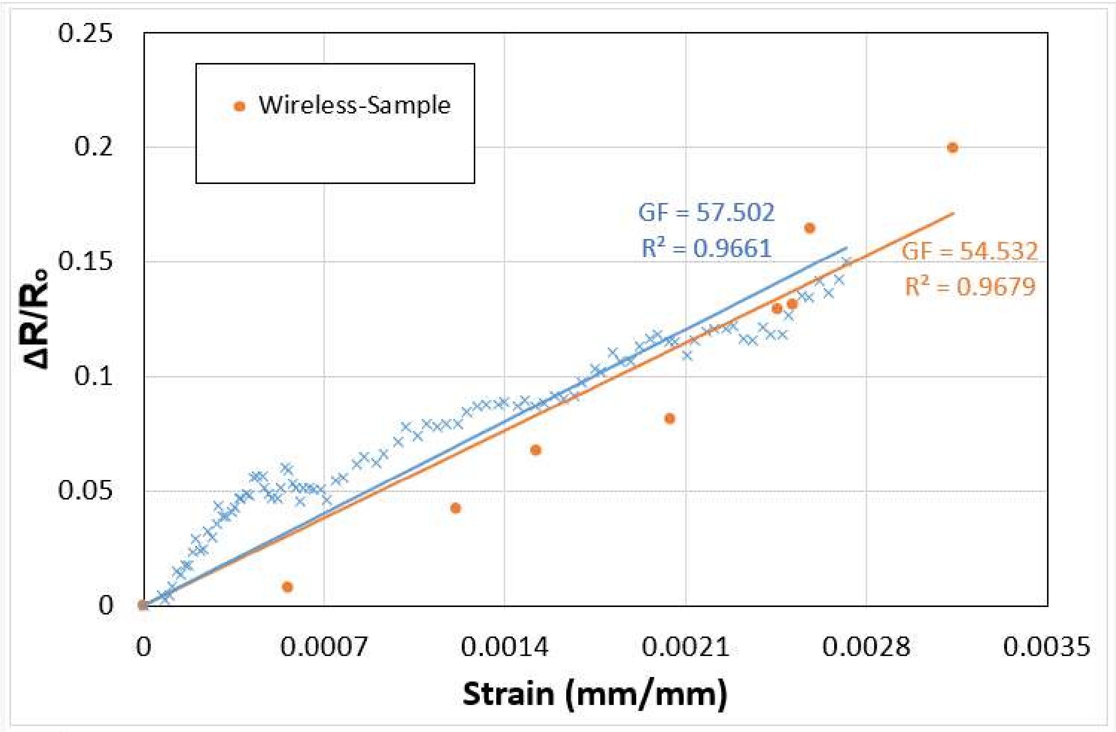

Figure 27: Gage Factor of Wireless Sensor

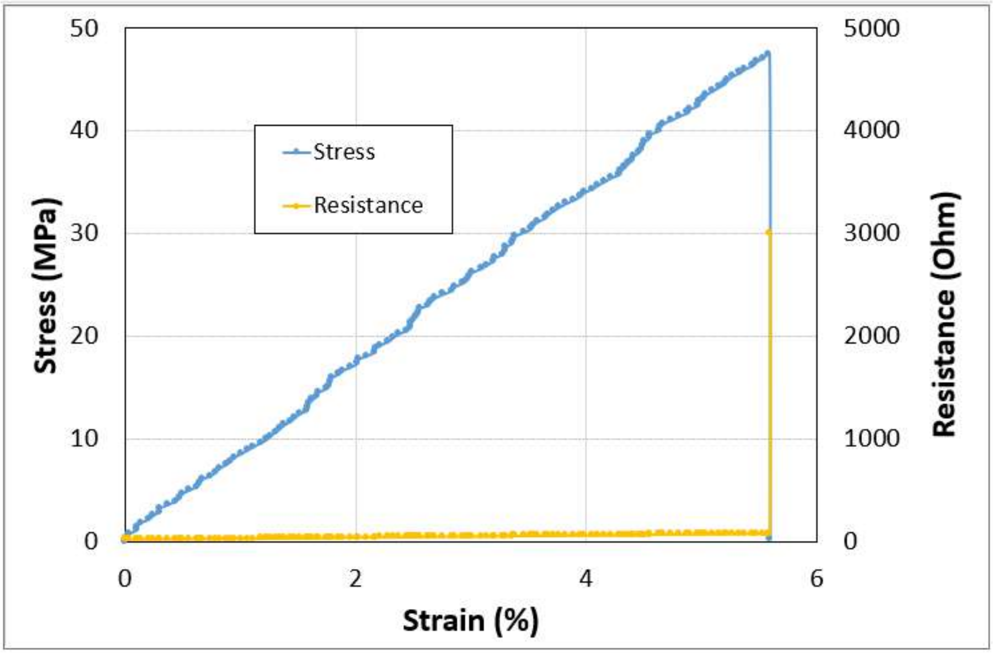

Figure 28: Strain Monitoring Response of Wireless Sensor

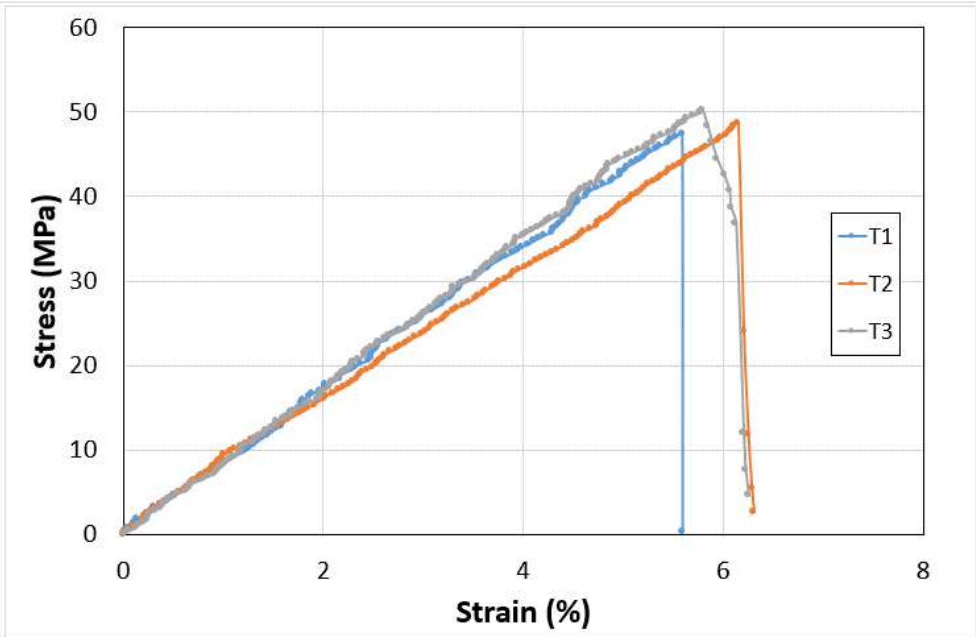

Figure 29: Reproducibility of Mechanical Response of Wireless Sensor

The figure 28 shows Strain monitoring response of the wireless sample, It indicates that for the wireless sample the resistance increased with increase in strain and the resistance peaked to the open circuit value at the point of rupture.

The figure 29 above shows the reproducible mechanical behavior of the wireless sample. It indicates that the wireless samples were mechanically consistent with each other. The maximum stress sustained before failure was close to 45Mpa.

4.4 Comparison of Wired And Wireless Sensor Results

The results of wired and wireless sensor have shown good agreement between the values. The gage factor obtained using the wired and wireless sensor also show the closeness between both. It indicated that the wireless sensor system developed is considerably accurate and is reliable.

Chapter 5: Conclusion

Based on the recent progress made in the project "Development of Multimode Wireless Sensor System for Real-time Monitoring," several significant advancements have been achieved. Initially, the electro less plating method successfully deposited a uniform silver coating on the outer surface of the nylon sample. The coating exhibited high quality and uniformity, with very little surface damage. The measurements indicated that the coated strand had a diameter of 20 µm and a thickness of 207 µm, resulting in a coating thickness of 2%. The characterization through EDS analysis confirmed a substantial weight percentage of silver on the surface, indicating a successful coating process, while the presence of carbon traces was attributed to environmental factors. XRD analysis further validated the deposition of silver elements on the Nylon yarn, ensuring the quality of the coating. Also, the electrical resistance measurement demonstrated the successful transformation of the nylon yarn into an electrical conductor.

The determination of gauge factor was done too using the DAQ system in contact with the Universal Testing Machine (UTM). Through conducting multiple tastings, we have successfully devised a wireless system that exhibits auspicious and dependable data transmission. This accomplishment creates opportunities for the smooth incorporation of the sensor system that was developed into diverse monitoring applications.

A dashboard that is easy to use for the purpose of efficient visualization and analysis of data was developed. The dashboard functions as a comprehensive interface that facilitates access to and interpretation of the gathered sensor data. This capability empowers users to make informed decisions based on real-time monitoring information.

It can be asserted that the advancements achieved in this project are significant. The electroless plating technique has demonstrated significant efficacy in producing high-quality silver-coated nylon, with potential applications in the domain of structural health monitoring and other sensing units. Likewise, the computation of the gauge factor, efficacious establishment of the wireless module and data transmission system, and the formulation of a user-friendly dashboard serve to enhance the comprehensive triumph of the undertaking. The technological progress establishes a firm groundwork for the ensuing phases of the undertaking, facilitating the creation of a durable and adaptable wireless sensor network capable of multifaceted operations for instantaneous surveillance.

References

[1] M. Mishra, P. B. Lourenço, and G. v Ramana, "Structural health monitoring of civil engineering structures by using the internet of things: A review," Journal of Building Engineering, vol. 48, p. 103954, 2022, doi: https://doi.org/10.1016/j.jobe.2021.103954.

[2] Y. Qureshi, M. Tarfaoui, K. Lafdi, and K. Lafdi, "Development of microscale flexible nylon/Ag strain sensor wire for real-time monitoring and damage detection in composite structures subjected to three-point bend test," Compos Sci Technol, vol. 181, p. 107693, Feb. 2019, doi: 10.1016/j.compscitech.2019.107693.

[3] P. M. Ferreira, M. A. Machado, M. S. Carvalho, and C. Vidal, "Embedded Sensors for Structural Health Monitoring: Methodologies and Applications Review," Sensors, vol. 22, no. 21, 2022, doi: 10.3390/s22218320.

[4] S. A, J. Regita, B. Rane, and H. H. Lau, "Structural health monitoring using wireless smart sensor network - An overview," Mech Syst Signal Process, vol. 163, Feb. 2021, doi: 10.1016/j.ymssp.2021.108113.

[5] B. Glisic, "Concise Historic Overview of Strain Sensors Used in the Monitoring of Civil Structures: The First One Hundred Years," Sensors, vol. 22, no. 6, 2022, doi: 10.3390/s22062397.

[6] S. Yan, H. Ma, P. Li, G. Song, and J. Wu, "Development and Application of a Structural Health Monitoring System Based on Wireless Smart Aggregates," Sensors, vol. 17, no. 7, 2017, doi: 10.3390/s17071641.

[7] Y. Qureshi, M. Tarfaoui, K. Lafdi, and K. Lafdi, "Real-time strain monitoring and damage detection of composites in different directions of the applied load using a microscale flexible Nylon/Ag strain sensor," Struct Health Monit, vol. 19, p. 147592171986998, Feb. 2019, doi: 10.1177/1475921719869986.

[8] V. Montazer Majid and Allahyarzadeh, "Electroless Plating of Silver Nanoparticles/Nanolayer on Polyester Fabric Using AgNO3/NaOH and Ammonia," Ind Eng Chem Res, vol. 52, no. 25, pp. 8436-8444, Jun. 2013, doi: 10.1021/ie400804n.

[9] M. Chen, "A Method of Electroless Silver Plating on the Surface of PA6 Fiber," IOP Conf Ser Mater Sci Eng, vol. 774, p. 12045, Feb. 2020, doi: 10.1088/1757-899X/774/1/012045.

[10] Y. and C. X. and K. Y. Huang Chongjun and Cai, "Silver-based nanocomposite for fabricating high performance value-added cotton," Cellulose, vol. 29, no. 2, pp. 723-750, Jan. 2022, doi: 10.1007/s10570-021-04257-z.

[11] H. L. Poon, "Applications of data acquisition systems," Comput Ind, vol. 13, no. 1, pp. 49-59, 1989, doi: https://doi.org/10.1016/0166-3615(89)90085-7.

[12] Z. Jiawei, "The Application of Structural Health Monitoring in Different Engineering Fields," IOP Conf Ser Earth Environ Sci, vol. 643, p. 12164, Feb. 2021, doi: 10.1088/1755-1315/643/1/012164.

[13] R. E. T. Amaladosson, J. Jawahar Kirubakaran, and I. Lakshmanan, "DEVELOPMENT OF STRUCTURAL HEALTH MONITORING SYSTEM - THE STATE-OF-THE ART-REVIEW,"Feb. 2018.

[14] E. and N. M. and Y. T. Y. and L. S. and N. A. and M.-C. C. and G. P. and M. S. Gharehbaghi Vahid Reza and Noroozinejad Farsangi, "A Critical Review on Structural Health Monitoring: Definitions, Methods, and Perspectives," Archives of Computational Methods in Engineering, vol.29, no. 4, pp. 2209-2235, Jun. 2022, doi: 10.1007/s11831-021-09665-9.

[15] P. Kot, M. Muradov, M. Gkantou, G. S. Kamaris, K. Hashim, and D. Yeboah, "Recent Advancements in Non-Destructive Testing Techniques for Structural Health Monitoring," Applied Sciences, vol. 11, no. 6, 2021, doi: 10.3390/app11062750.

[16] R. F. Gibson, "A review of recent research on mechanics of multifunctional composite materials and structures," Compos Struct, vol. 92, no. 12, pp. 2793-2810, 2010, doi: https://doi.org/10.1016/j.compstruct.2010.05.003.

[17] W. Wang, Y. Xiang, J. Yu, and L. Yang, "Development and Prospect of Smart Materials and Structures for Aerospace Sensing Systems and Applications," Sensors, vol. 23, no. 3, 2023, doi: 10.3390/s23031545.

[18] G. Georgousis et al., "Strain sensing in polymer/carbon nanotube composites by electrical resistance measurement," Compos B Eng, vol. 68, pp. 162-169, 2015, doi: https://doi.org/10.1016/j.compositesb.2014.08.027.

[19] I. Kang et al., "Introduction to carbon nanotube and nanofiber smart materials," Compos B Eng, vol. 37, no. 6, pp. 382-394, 2006, doi: https://doi.org/10.1016/j.compositesb.2006.02.011.

[20] A. Asar, M. S. Irfan, K. A. Khan, W. Zaki, and R. Umer, "Self-sensing shape memory polymer composites reinforced with functional textiles," Compos Sci Technol, vol. 221, p. 109219, 2022, doi: https://doi.org/10.1016/j.compscitech.2021.109219.

[21] T. Dayyoub, A. v Maksimkin, O. v Filippova, V. v Tcherdyntsev, and D. v Telyshev, "Shape Memory Polymers as Smart Materials: A Review," Polymers (Basel), vol. 14, no. 17, 2022, doi: 10.3390/polym14173511.

[22] B. Aïssa, D. Therriault, E. Haddad, and W. Jamroz, "Self-Healing Materials Systems: Overview of Major Approaches and Recent Developed Technologies," Advances in Materials Science and Engineering, vol. 2012, pp. 1-17, 2012, doi: 10.1155/2012/854203.

[23] W. Wang, Y. Xiang, J. Yu, and L. Yang, "Development and Prospect of Smart Materials and Structures for Aerospace Sensing Systems and Applications," Sensors, vol. 23, no. 3, 2023, doi: 10.3390/s23031545.

[24] A. Noel, A. Abdaoui, A. Badawy, T. El-Fouly, M. Ahmed, and M. Shehata, "Structural Health Monitoring Using Wireless Sensor Networks: A Comprehensive Survey," IEEE Communications Surveys & Tutorials, vol. PP, p. 1, Feb. 2017, doi: 10.1109/COMST.2017.2691551.

[25] L. Gallucci et al., "An Embedded Wireless Sensor Network with Wireless Power Transmission Capability for the Structural Health Monitoring of Reinforced Concrete Structures," Sensors, vol. 17, no. 11, 2017, doi: 10.3390/s17112566.

[26] D. Kandris, C. Nakas, D. Vomvas, and G. Koulouras, "Applications of Wireless Sensor Networks: An Up-to-Date Survey," Applied System Innovation, vol. 3, no. 1, p. 14, Feb. 2020, doi: 10.3390/asi3010014.

[27] T.-H. Zhou Guang-Dong and Yi, "Recent Developments on Wireless Sensor Networks Technologyfor Bridge Health Monitoring," Math Probl Eng, vol. 2013, p. 947867, Dec. 2013, doi: 10.1155/2013/947867.

[28] G.-X. and S. P. and W. L.-Y. and Y. Q. Ding You-Liang and Wang, "Long-Term Structural HealthMonitoring System for a High-Speed Railway Bridge Structure," The Scientific World Journal, vol. 2015, p. 250562, Sep. 2015, doi: 10.1155/2015/250562.

[29] I. G. A. Poornima and B. Paramasivan, "Anomaly detection in wireless sensor network usingmachine learning algorithm," Comput Commun, vol. 151, pp. 331- 337, 2020, doi: https://doi.org/10.1016/j.comcom.2020.01.005.

[30] J. Cao and X. Liu, "Structural Health Monitoring Using Wireless Sensor Networks," Mobile and Pervasive Computing in Construction, pp. 210-236, Feb. 2012, doi: 10.1002/9781118422281.ch11.

[31] X. and F. J. Luan Congcong and Yao, "Fabrication and characterization of in situ structural health monitoring hybrid continuous carbon/glass fiber-reinforced thermoplastic composite," The International Journal of Advanced Manufacturing Technology, vol. 116, no. 9, pp. 3207-3215, Oct. 2021, doi: 10.1007/s00170-021- 07666-3.

[32] M. Azimi, A. D. Eslamlou, and G. Pekcan, "Data-Driven Structural Health Monitoring and Damage Detection through Deep Learning: State-of-the-Art Review," Sensors, vol. 20, no. 10,2020, doi: 10.3390/s20102778.

[33] V. Naraharisetty, V. Talari, S. Neridu, P. Kalapatapu, and V. Pasupuleti, "Proposed Cloud Architecture for Real-Time Bridge Monitoring Using IOT," 2023, pp. 195-203. doi: 10.1007/978-3-031-07258-1_21.

[34] Y.-L. Ding, P. Ren, H.-W. Zhao, and C.-Q. Miao, "Structural health monitoring of a high-speedrailway bridge: five years review and lessons learned," Feb. 2017.

[35] X. Zhao, Y. Yu, M. Li, and J. Ou, "Research on Cloud-SHM and its applications," Feb. 2015

Annexure

Arduino Code

```
#include <Wire.h>

#include <Adafruit_ADS1X15.h>

#include <FirebaseESP32.h>

Adafruit_ADS1115 ads;    // Create an ADS1115 object

const int adsAddress = 0x48;   // ADS1115 I2C address (default)

float voltageDrop;   // Variable to store the voltage drop

#define FIREBASE_HOST "https://dummy-data-774b0-default-rtdb.europe-west1.firebasedatabase.app/"

#define FIREBASE_AUTH "AIzaSyCi06RZhGYuCbAfIrqfvFfssMITICAeC1o"

#define WIFI_SSID "Tenda_A36A68"

#define WIFI_PASSWORD "0572351086"

FirebaseData firebaseData;

FirebaseJson json;

void setup() {

Serial.begin(115200);   // Start serial communication

ads.begin(adsAddress);   // Initialize the ADS1115

//Serial.begin(9600);

WiFi.begin(WIFI_SSID, WIFI_PASSWORD);

Serial.print("Connecting to Wi-Fi");

while (WiFi.status() != WL_CONNECTED)

{

Serial.print(".");
```

```
delay(300);

}

Serial.println();

Serial.print("Connected with IP: ");

Serial.println(WiFi.localIP());

Serial.println();

Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH);

Firebase.reconnectWiFi(true);

//Set database read timeout to 1 minute (max 15 minutes)

Firebase.setReadTimeout(firebaseData, 1000 * 60);

//tiny, small, medium, large and unlimited.

//Size and its write timeout e.g. tiny (1s), small (10s), medium (30s) and large (60s).

Firebase.setwriteSizeLimit(firebaseData, "tiny");

/*

This option allows get and delete functions (PUT and DELETE HTTP requests)
works for device connected behind the

Firewall that allows only GET and POST requests.

Firebase.enableClassicRequest(firebaseData, true);

*/

//String path = "/data";

Serial.println("------------------------------------");

Serial.println("Connected...");

}

void loop() {
```

```
int16_t adc0 = ads.readADC_SingleEnded(0);   // Read the voltage value from AIN0

// Calculate the voltage using the formula

float voltage = adc0 * 0.1875;

// Store the voltage drop

voltageDrop = voltage/1000;

float i=((3.3-voltageDrop)/1000);

float r=voltageDrop/i;

Serial.print("Voltage Drop: ");

Serial.print(voltageDrop);

Serial.println(" V");

Serial.print(r);

Serial.println(" Ohms");

json.set("/Reading1", r); // Place your sensor data here

Firebase.updateNode(firebaseData,"/Sensor",json);

delay(1000);  // Delay for 1 second
```

HTML code

```
<!DOCTYPE html>

<html lang="en">

<head>

<meta charset="UTF-8" />

<meta name="viewport" content="width=device-width, initial-scale=1.0" />

<link

rel="apple-touch-icon"

sizes="180x180"

href="images/apple-touch-icon.png"

/>

<link

rel="icon"

type="image/png"

sizes="32x32"

href="images/favicon-32x32.png"

/>

<link

rel="icon"

type="image/png"

sizes="16x16"

href="images/favicon-16x16.png"

/>

<link rel="manifest" href="/site.webmanifest" />
```

```
<link
href="https://fonts.googleapis.com/icon?family=Material+Icons+Sharp"
rel="stylesheet"
/>
<link rel="stylesheet" href="style.css" />
<link
href="https://cdn.jsdelivr.net/npm/bootstrap@5.3.0/dist/css/bootstrap.min.css"
rel="stylesheet"
integrity="sha384-
9ndCyUaIbzAi2FUVXJi0CjmCapSmO7SnpJef0486qhLnuZ2cdeRhO02iuK6FUUV
M"
crossorigin="anonymous"
/>
<script
src="https://cdn.jsdelivr.net/npm/bootstrap@5.3.0/dist/js/bootstrap.bundle.min.js"
integrity="sha384-
geWF76RCwLtnZ8qwWowPQNguL3RmwHVBC9FhGdlKrxdiJJigb/j/68SIy3Te4Bk
z"
crossorigin="anonymous"
></script>
<script src="stats.js"></script>
<title>SENSOR MONITORING DASHBOARD</title>
</head>
<body>
<div class="myContainer">
<!-- Sidebar Section -->
```

```
<aside style="position: sticky; top: 0; left: 0">
<div class="toggle" style="position: sticky">
<div class="logo">
<!-- <img src="images/logo.png" /> -->
<h3 style="font-size: 14px">
SENSOR<span class="danger">MONITORING</span>
</h3>
</div>
<div class="close" id="close-btn">
<span class="material-icons-sharp"> close </span>
</div>
</div>
<div class="mySidebar" style="position: sticky">
<a href="#">
<span class="material-icons-sharp"> dashboard </span>
<h2 style="font-size: 16px">Dashboard</h2>
</a>
<a href="#">
<span class="material-icons-sharp"> person_outline </span>
<h3 style="font-size: 14px">Users</h3>
</a>
<a href="#">
<span class="material-icons-sharp"> receipt_long </span>
<h3 class="fnt">History</h3>
```

```
</a>
<a href="#" id="strain" onclick="toggleChartContainer()">
<span class="material-icons-sharp"> insights </span>
<h3 style="font-size: 14px">Strain Sensor</h3>
</a>
<a href="#" id="temp" onclick="toggleChartContainer1()">
<span class="material-icons-sharp"> device_thermostat </span>
<h3 style="font-size: 14px">Temperature Sensor</h3>
</a>
<a href="#" id="vib" onclick="toggleChartContainer2()">
<span class="material-icons-sharp"> vibration </span>
<h3 style="font-size: 14px">Vibration Sensor</h3>
</a>
<a href="#" id="pre" onclick="toggleChartContainer3()">
<span class="material-icons-sharp"> compress </span>
<h3 style="font-size: 14px">Pressure Sensor</h3>
</a>
<a href="#">
<span class="material-icons-sharp"> settings </span>
<h3 style="font-size: 14px">Settings</h3>
</a>
<a href="#">
<span class="material-icons-sharp"> add </span>
<h3 style="font-size: 14px">New Login</h3>
```

```
</a>
<a href="#">
<span class="material-icons-sharp"> logout </span>
<h3 style="font-size: 14px">Logout</h3>
</a>
</div>
</aside>
<!-- End of Sidebar Section -->


<!-- Main Content -->
<main>
<h1>Sensors Analytics</h1>
<div
id="chartContainer1"
style="height: 370px; width: 100%; position: relative"
></div>
<!-- <hr /> -->
<div
id="dummyChart"
style="height: 320px; width: 70%; position: relative"
>
<img
src="./images/temperature.png"
alt=""
```

```
style="position: relative; margin-bottom: 20px"
/>
</div>
<!-- <hr /> -->
<div
id="vibration"
style="height: 320px; width: 70%; position: relative"
>
<img
src="./images/vibration.png"
alt=""
style="position: relative; margin-bottom: 20px"
/>
</div>
<!-- <hr /> -->
<div
id="pressure"
style="height: 320px; width: 70%; position: relative"
>
<img
src="./images/pressure.png"
alt=""
style="position: relative; margin-bottom: 20px"
/>
```

```
</div>
<!-- <hr /> -->
<!-- Recent Orders Table -->
<div class="recent-orders">
<h2>Recent Statistics</h2>
<table>
<thead>
<tr>
<th>Time</th>
<th>Resistance <span>&ohm;</span></th>
<th>Average <span>&ohm;</span>/s</th>
<th>Status</th>
<th></th>
</tr>
</thead>
<tbody></tbody>
</table>
<a href="#">Show All</a>
</div>
<!-- End of Recent Orders -->
<div
class="modal fade"
id="exampleModal"
tabindex="-1"
```

```
aria-labelledby="exampleModalLabel"
aria-hidden="true"
>
<div class="modal-dialog">
<div class="modal-content">
<div class="modal-header">
<h1 class="modal-title fs-5" id="exampleModalLabel">
Add Readings in Firebase.
</h1>
<button
type="button"
class="btn-close"
data-bs-dismiss="modal"
aria-label="Close"
></button>
</div>
<div class="modal-body">
<form>
<div class="mb-3">
<label for="recipient-name" class="col-form-label"
>Reading Value:</label          >
<input
placeholder="Enter label here"
type="text"
```

```
class="form-control"
id="reading"
/>
<br />
<input
placeholder="Enter reading value"
type="number"
class="form-control"
id="val"
/>
</div>
</form>
</div>
<div class="modal-footer">
<button
type="button"
class="btn btn-secondary"
data-bs-dismiss="modal"
>
Close
</button>
<button type="button" class="btn btn-primary" onclick="save()">
Add
</button>
```

```
</div>

</div>

</div>

</div>

</main>

<!-- End of Main Content -->

<!-- Right Section -->

<div class="right-section">

<div class="nav">

<button id="menu-btn">

<span class="material-icons-sharp"> menu </span>

</button>

<div class="dark-mode">

<span class="material-icons-sharp active"> light_mode </span>

<span class="material-icons-sharp"> dark_mode </span>

</div>

<div class="profile">

<div class="info">

<p>Hey, <b>XYZ</b></p>

<small class="text-muted">Admin</small>

</div>

<div class="profile-photo">

<img src="images/profile-1.jpg" />

</div>
```

```
</div>
</div>
<!-- End of Nav -->
<!-- <div class="user-profile">
<div class="logo">
<img src="images/logo.png" />
<h2>Muhammad Arshad</h2>
<p>Fullstack Web Developer</p>
</div>
</div> -->
<div class="reminders">
<div class="header">
<h2>Reminders</h2>
<span class="material-icons-sharp"> notifications_none </span>
</div>
<div class="notification">
<div class="icon">
<span class="material-icons-sharp"> volume_up </span>
</div>
<div class="content">
<div class="info">
<h3>Workshop</h3>
<small class="text_muted"> 08:00 AM - 12:00 PM </small>
</div>
```

```
<span class="material-icons-sharp"> more_vert </span>
</div>
</div>

<div class="notification deactive">
<div class="icon">
<span class="material-icons-sharp"> edit </span>
</div>
<div class="content">
<div class="info">
<h3>Conference</h3>
<small class="text_muted"> 08:00 AM - 1:00 PM </small>
</div>
<span class="material-icons-sharp"> more_vert </span>
</div>
</div>
<div class="notification deactive">
<div class="icon">
<span class="material-icons-sharp"> edit </span>
</div>
<div class="content">
<div class="info">
<h3>Meeting</h3>
<small class="text_muted"> 06:00 PM - 7:00 PM </small>
```

```
</div>
<span class="material-icons-sharp"> more_vert </span>
</div>
</div>
<div class="notification add-reminder">
<div>
<span class="material-icons-sharp"> add </span>
<a href="#" class="active">
<button
type="button"
class="btn btn-primary"
data-bs-toggle="modal"
data-bs-target="#exampleModal"
data-bs-whatever="@mdo">
<h3>Add Sensor Values</h3>
</button>
</a>
</div>
</div>
</div>
</div>
</div>
<script src="https://www.gstatic.com/firebasejs/8.3.1/firebase-app.js"></script>
<script src="https://www.gstatic.com/firebasejs/8.3.1/firebase-database.js"></script>
```

```
<script src="index.js"></script>

<script src="index1.js"></script>

<script src="https://cdn.canvasjs.com/canvasjs.min.js"></script>

<script src="https://canvasjs.com/assets/script/jquery-1.11.1.min.js"></script>

<script src="https://cdn.canvasjs.com/jquery.canvasjs.min.js"></script>

</body>

</html>
```