

**Dhaka University Nanotechnology Center (DUNC)  
University of Dhaka  
Dhaka-1000, Bangladesh**

**Inception Report 2025-26**

**1. Summary of the proposal (Max 200 words: Proposal at a glance):**

Achieving control over size and molecular weight of polyaniline (PAni) plays crucial role in conductivity for their use as shielding material in smart textile and this still remains a challenging task. In the proposed work, attempt will be made to regulate not only size but also molecular weight of PAni, synthesized from aniline using Triton X-100-based w/o microemulsion as a nanoreactor. The analysis will be focused on the effect of changing two synthesis parameters such as water-to-surfactant molar ratio of microemulsion and temperature on the size and molecular weight of PAni which ultimately expected to affect the conductivity. The prepared material will be characterized to explore the prospect in electromagnetic interference (EMI) shielding in smart textile applications. So, the proposed work would open routes to tune conductive property of synthesized PAni for efficient EMI shielding.

**2. Introduction:**

Smart textiles represent a state-of-art class of materials that integrate conventional fabrics with functional components, enabling capabilities such as sensing, actuation, and adaptive responses to electrical, mechanical, or environmental impulses. Because of their broad application potential, these innovative textile systems have attracted significant scientific attention in areas including biomedical devices, EMI shielding, energy storage systems, and communication technologies [1]. Traditional textile materials are generally electrically insulating in nature, which prevents their direct use in smart textile, particularly in EMI shielding application that demands electrical conductivity. It is possible to obtain electrically conductive textile by integrating metallic wires. Examples include metal-based wearable shielding materials, such as Silver/Nylon, Nickel-Copper/Nylon, and Steel/Nylon. These materials possess several limitations including high density, stiffness, susceptibility to corrosion, high manufacturing costs due to the scarcity of certain metals [2-4]. To address these limitations and fulfill the requirement of having electrical conductivity of EMI shielding materials to effectively interact with electromagnetic waves, intrinsically conductive polymers are introduced which offer enhanced or entirely novel properties.

Among other conductive polymers, PAni has been explored as potential corrosion-resistant, lightweight, environmentally stable alternative to metals in EMI shielding applications [5-7].



The most striking feature of PANi is that it can be converted, under certain experimental conditions, to an insulator from a conductor. In the emeraldine salt form of PANi, polarons and bipolarons act as charge carriers and allow charge to move along the conjugated polymer backbone. Because PANi has an extended  $\pi$ -conjugated system, the charges become delocalized, enabling electrical conduction. The size and molecular weight of PANi are two parameters which have great influence on different properties of PANi. Conductivity depends not only on oxidation state of PANi but also may vary with size as well as molecular weight of PANi particles individually [8,9].

Polymers synthesized using conventional emulsion polymerization method are larger in size and broader in size range. Again, the size of PANi can hardly be controlled by solution polymerization [10]. Microemulsion polymerization can be an effective method in producing polymer particles with controllable size. Microemulsions are thermodynamically stable microheterogeneous systems where a polar component is dispersed in a non-polar component or vice versa. Because the polymerization of aniline proceeds in a molecularly ordered system, synthesis of PANi with tunable size is possible by synthesizing it within the core of dispersed phase in microemulsion [11]. However, while this technique enables tunability on size of PANi, the control over its molecular weight using this method has not been well explored in the literature. Besides study on simultaneous tuning of molecular weight and size is also insufficient. Again, effect of tunability over the size and molecular weight of PANi on the conductivity and EMI shielding effectiveness has not been well explored in the literature. This research seeks to address these limitations and give an insight in structure-property relationships of PANi to act as an effective EMI shielding material.

### **3. Background of the Research:**

EMI shielding involves the use of materials that reduce the transmission of electromagnetic waves by reflecting or absorbing the incident radiation. Since electromagnetic radiation often exists at high frequencies and can significantly disrupt electronic devices, EMI shielding plays a critical role in ensuring the proper functioning and protection of electronic systems [12,13]. To achieve effective EMI shielding, the presence of mobile charge carriers, such as free electrons or holes, is essential in the shielding material. The reflection loss, which represents the dominant shielding mechanism, is directly proportional to the electrical conductivity of the material. Consequently, materials with high electrical conductivity are generally favored for efficient EMI shielding applications.

PANi, an intrinsically conducting polymer, is widely regarded as a promising candidate for introducing electrical conductivity into naturally insulating textile substrates which can act as EMI shielding material. It has gained considerable attention as a conductive material due to its lightweight nature, low cost, tunable electrical conductivity, mechanical flexibility, and biocompatibility. Conductive polymers such as PANi are therefore well suited for developing

lightweight smart materials which is suitable for EMI shielding without the need for metallic components [14]. The factors such as molecular weight and particle size of PANi can be driving forces to achieve high conductivity in this regard.

#### **4. Research Questions and Objectives:**

Despite the promising potential of PANi as a lightweight and corrosion-resistant alternative to metals in EMI shielding textiles, several fundamental questions remain unanswered. The size effect of PANi on the EMI shielding has remained unexplored. The independent influence of molecular weight as well as the simultaneous tuning of particle size and molecular weight on the structure-property-performance relationship in PANi-based systems for EMI shielding application is a new interest to explore. Microemulsion enables tunability over size which is already reported but its influence on the tunability of molecular weight is not investigated yet.

The primary objective of this research is to systematically synthesize PANi with tunable particle size and molecular weight using microemulsion polymerization and to establish a clear correlation between these structural parameters and conductivity which is a functional property. For this, the study aims to (i) develop a controlled synthesis strategy to independently and simultaneously tailor particle size and molecular weight, (ii) characterize the resulting materials in terms of size, molecular weight distribution, and electrical conductivity, and (iii) evaluate their EMI shielding effectiveness to determine structure-property-performance relationships. Ultimately, this work seeks to provide a mechanistic understanding of how structural tunability influences charge transport and electromagnetic wave attenuation, thereby enabling the rational design of high-performance PANi-based conductive textiles for advanced EMI shielding applications.

#### **5. Theoretical framework, if required: Not required**

#### **6. Analytical/Operational Framework, if required: Not required**

#### **7. Detailed Methodology:**

##### **a. Research Methods:**

PANi will be synthesized using TX-100 based w/o microemulsion as a nanoreactor at a fixed temperature varying water-to-surfactant molar ratio to observe the dependence of size of the PANi particle on the core size of microemulsion. Temperature variation will be carried out for a specific core size to observe the simultaneous effect on size and molecular weight. The conductivity of the synthesized PANi will be investigated.

In the second part, the PANi will be coated onto fabrics using dip-coating or spray-coating techniques and the influence of particle size and molecular weight on charge transport and mechanical adhesion will be investigated in detail. Finally, the efficiency of the PANi coated fabrics on EMI shielding will be investigated.

**b. Data Collection Techniques: Sources of data and data collection tools and techniques:**

Machine generated data will be used and analyses will be carried out following standard procedures.

**c. Detailed Sampling: techniques, size, area/location of data collection and nature of respondents, number of enumerators, if required:** Not applicable

**d. Machine, Materials and Technologies to be used (in details):**

The parameters which are varied during the synthesis of PANi are-

(i) water-to-surfactant molar ratio and (ii) temperature. Tuning such parameters will give a clear picture of the tunability of size and molecular weight. This regulation will create additional opportunities for improving both electrical conductivity and mechanical durability in EMI shielding in smart textile applications.

The synthesized PANi will be characterized by UV-visible spectroscopy and Fourier transform infrared (FTIR) spectroscopy for the confirmation of PANi formation via the appearance of peaks of  $\pi$ - $\pi^*$  transition of benzenoid ring and  $n$ - $\pi^*$  transition of quinonoid moiety in UV-visible spectra and specific bands of quinonoid and benzenoid ring in FTIR spectra respectively. The thermal stability will be investigated using thermogravimetric analyzer (TGA). The hydrodynamic diameter and particle size will be examined through dynamic light scattering (DLS) and field emission scanning electron microscopy (FESEM) respectively. The molecular weight of PANi will be determined using static light scattering (SLS). From the Nyquist plot of electrochemical impedance spectroscopy (EIS), the conductivity will be determined. The EMI shielding effectiveness of PANi incorporated fabrics will be performed via four-point probe conductivity measurements. These thorough characterizations will confirm the suitability of the PANi as an effective EMI shielding materials in smart textile applications.

**8. Data Analysis Mechanism:**

Data will be analyzed systematically and compared with the standard values available in literature.

## **9. Expected Output and Outcome:**

PAni in EMI shielding in smart textiles are primarily sought after for their ability to form uniform conductive networks while offering adjustable electrical conductivity, mechanical flexibility, and resistance to washing and wear. A systematic variation of the water-to-surfactant molar ratio in the w/o microemulsion will reveal a direct correlation between the microemulsion core size and the resulting PAni particle size. Temperature optimization for a fixed core size will demonstrate its influence on both particle size and molecular weight, providing insight into how thermal energy affects chain propagation and polymer growth. PAni synthesized under optimized conditions is expected to show higher electrical conductivity, as conductivity is influenced by both particle size and molecular weight.

PAni-coated fabrics are expected to exhibit enhanced EMI shielding effectiveness due to the combination of high conductivity and uniform nanoparticle distribution. The study will identify the optimal particle size and molecular weight for maximum shielding, contributing directly to the design of smart textiles for wearable electronics, defense, or healthcare applications. The research will provide a comprehensive understanding of how the parameter, water-to-surfactant molar ratio of microemulsion and temperature influence PAni conductivity. This knowledge will enable rational design of conductive polymer of PAni for flexible, lightweight, and high-performance EMI shielding materials.

## **10. Organization of the Final Report/Tentative Chapters:**

The final report will be consisted of the following Chapters in the following order:

1. Abstract/Summary
2. Introduction
3. Background/Literature Review
4. Materials and Methods
5. Results and Discussion
6. Conclusions
7. References
8. Acknowledgement

## **11. Detailed Budget as Per Allocation:**

(a) Research Fellowship:  $12,000 \times 12 = 1,44,000$  TK

(b) Equipment:

(c) Other Accessories/Chemicals:

(d) Contingency: 16,000 TK

(e) Analytical Services:

Total: 1,60,000 TK

## **12. Timeframe of the Research (Gantt Chart):**

The research has been initiated as a part of MS thesis in the physical chemistry research laboratory of Department of Chemistry at University of Dhaka. The research will be completed within the 2025-26 academic year.

## **13. Limitations of the Study:**

Research based on polymer chemistry for smart textiles is frequently hindered in Bangladesh by restricted availability of advanced instrumentation, inadequate maintenance infrastructure, and insufficient funding for high-resolution nanoscale analysis. This study focuses on the effect of size and molecular weight of PANi on conductivity and their integration in textile. Quite surprisingly, there is no gel permeation chromatography (GPC) system in Bangladesh, which is a fundamental analytical technique for research on polymer science. This enables precise determination of molecular weight distribution (number-average and weight-average molecular weights) and polydispersity index of not only polymers but also polymer-based nanocomposites. The absence of a GPC facility in Bangladesh severely hinders polymer characterization and constrains high-impact research since the performance of advanced textile materials is strongly influenced by the molecular weight distribution of the polymers. Besides, to determine the appropriate particle size, transmission electron microscopy (TEM) is essential. Many renowned journals in materials science and nanotechnology frequently use TEM images for morphology validation. TEM facilities remain unavailable across major institutions including Dhaka University hindering publication of this work without external collaborations. As the leading research institution in Bangladesh, Dhaka University should place strong emphasis on acquiring instruments like GPC and TEM system and developing trained specialists to operate it, thereby strengthening local research capacity in smart textile nanotechnology. Moreover, other existing facilities like FTIR, FESEM face operational limitations that impact the advanced research to a great extent.

## **14. Stakeholders Related to This Study and Expected Beneficiaries:**

The proposed study offers substantial impact by advancing both fundamental understanding and practical technological applications. Through a systematic investigation of the structure-property relationships of the conductive polymer PANi, it aims to achieve a deeper molecular-level understanding of charge transport behavior. These findings can provide a scientific basis for the rational design and selection of novel materials, extending beyond EMI shielding to a wide range of smart textile applications.

This research lies at the convergence of nanopolymer science, materials science, and textile engineering, providing a dynamic platform for innovation. Through a systematic evaluation of the structure–property relationships of PANi, the study can establish a guiding framework for investigating other polymer systems, thereby facilitating the development of new materials with customized electrical, mechanical, and functional properties. Such fundamental insights will broaden scientific understanding, inspire future interdisciplinary research, and support scholars in polymer science, materials science, and textile engineering who stand to benefit from these advancements.

As an M.S. student will be involved in the project, its execution will provide advanced scientific training without the need for additional personnel. The work will contribute to strengthening the knowledge base in this important research area, thereby supporting the broader objective of developing sustainable research capacity.

## 15. Acknowledgment:

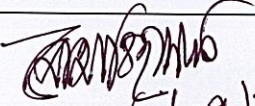
This work has been funded by Dhaka University Nanotechnology Centre (DUNC), University of Dhaka.

## 16. References:

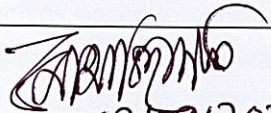
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**17. Signature of the Principal Investigator:**

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**18. Signature of the Director of the Entity:**

Name:
Signature:  Date:
<p>09/09/2025 Prof. Dr. Md. Abu Bin Hasan Susan Director Dhaka University Nanotechnology Centre (DUNC) University of Dhaka Dhaka-1000, Bangladesh</p>