

# **Synopsis**

of the thesis entitled

## **Polymer mediated Metal Nanoparticles and their Applications**

Submitted to

**THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA**

For the Degree of

*Doctor of Philosophy*

*In*

*Applied Chemistry*

By:

**Patel Saurav Sureshbhai**

Under the Supervision of

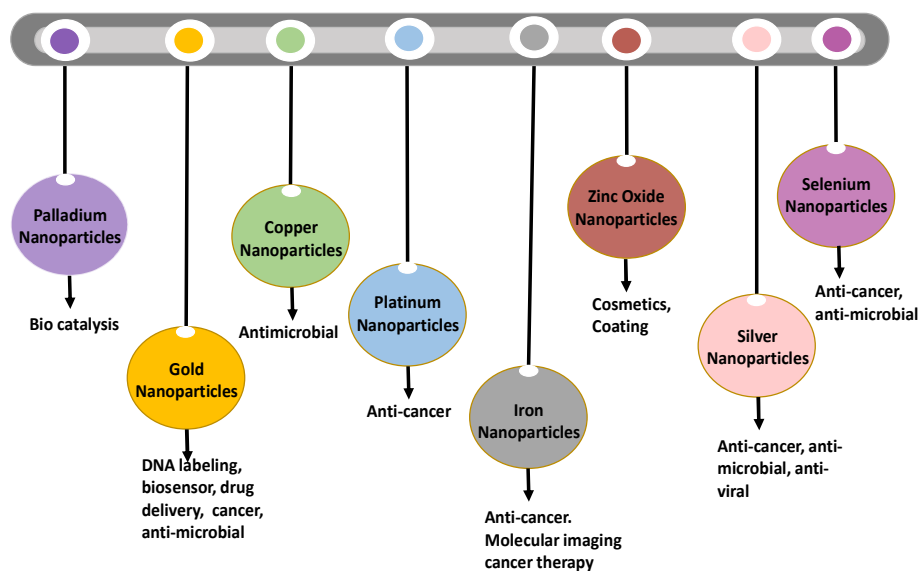
**Dr.Rakesh K. Sharma**

**Applied Chemistry Department  
Faculty of Technology and Engineering  
The Maharaja Sayajirao University of Baroda,  
Vadodara-390001, Gujarat, INDIA**

**December-2023**

## Polymer mediated Metal Nanoparticles and their Applications

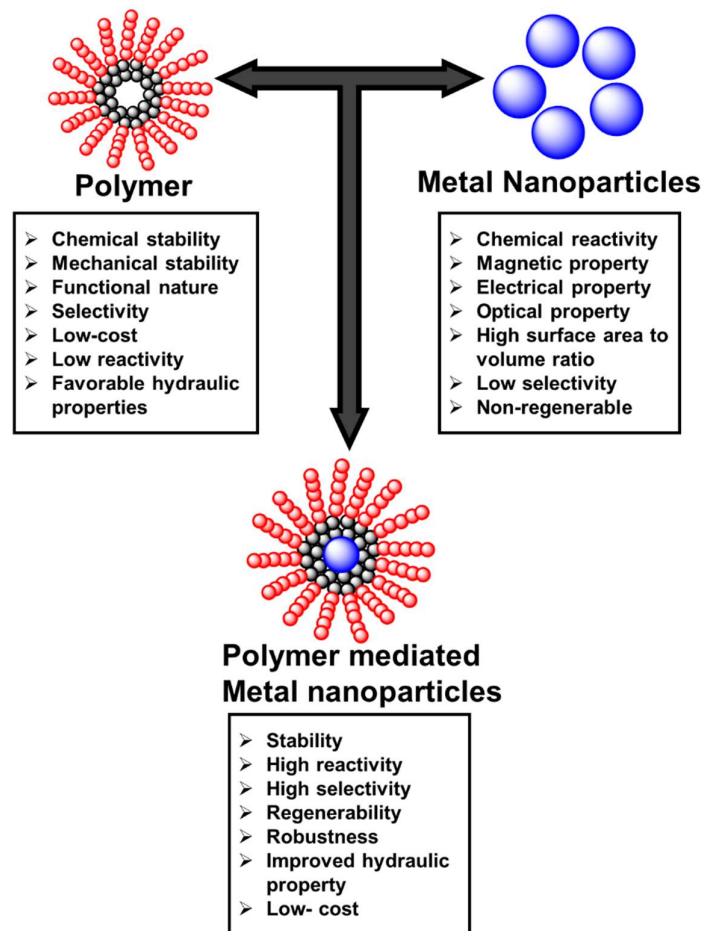
Metal nanoparticles (MNPs) are an attractive category of nanomaterials that have captured the interest of scientists, engineers, and researchers from several fields of study. The particles under consideration exhibit sizes that typically range from 1 to 100 nanometers [1, 2]. These particles are composed of a variety of metals, such as gold, silver, platinum, copper, silica, and other transition metals, among others. The interesting feature of MNPs is their unique and often unexpected characteristics that emerge at the nanoscale [3, 4]. The properties and behaviors of MNPs diverge dramatically from those of their bulk counterparts, and these distinctions open up a wealth of opportunities for innovation and application [5]. One of the most noticeable properties of MNPs is their size. At nano scale, the quantum confinement effects and surface effects become dominant, giving rise to a novel property. Size and shape control is a hallmark of MNPs research. Whether it's spheres, rods, triangles, cubes, or more complex geometries, researchers can precisely engineer the structure of these nanoparticles [6]. MNPs also exhibit high surface area relative to their volume. This high surface area of materials has a dual nature: on one hand, it makes them extremely effective for catalysis and adsorption, as more active sites are available for chemical reactions and molecule adsorption [7]. On the other hand, it can lead to increased reactivity and potential toxicity, which is an essential consideration in their use, especially in biomedical and environmental applications.



*Figure 1: Metal nanoparticles and their applications*

Polymers play an important role in the synthesis of MNPs, simplifying and enhancing the process. They act as versatile templates, stabilizers, and growth regulators for these tiny but potent materials. They serve as templates, offering a structured environment for the growth of MNPs. By modifying the polymer's properties, such as chain length or functional groups, one

can tailor the nanoparticles to desired specifications. Polymers also provide stability to metal nanoparticles, preventing them from clumping together or undergoing undesired reactions [8]. This stabilization effect is crucial for the long-term functionality of these nanoparticles, making them usable in various applications, from catalysis to biomedical devices [9]. Polymers, when used as capping agents or stabilizers, surround and shield the nanoparticles, preventing them from clumping together. This stabilizing effect is vital for maintaining the dispersibility and long-term stability of MNPs. Polymers can modify the surface chemistry of MNPs [10]. Polymer-mediated metal nanoparticles often exhibit enhanced properties compared to simple metal nanoparticles. For example, the polymer matrix can introduce additional functionalities, such as improved mechanical strength, increased biocompatibility, or enhanced electrical conductivity [9]. This combination of polymer and MNP properties opens up new possibilities for a wide range of applications.



**Figure 2:** Diverse properties of metal nanoparticles used for different environment application

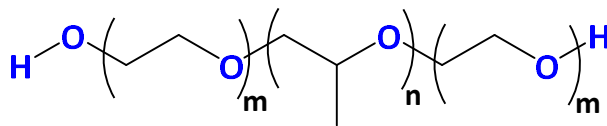
The amphiphilic block copolymers have played a vital role and this class of materials has been exploited in a variety of ways in the fields of chemistry, physics, material sciences, and biological sciences [11]. Triblock copolymers of poly(ethylene oxide) (PEO) and poly(propylene oxide) (PPO), also known as Ploxamers and sold commercially as Pluronic<sup>®</sup> (BASF), are known for their surface-active properties, which come from their non-compatible blocks (hydrophilic PEO and hydrophobic PPO) [12]. These Pluronic

polymers (*PEO-PPO-PEO block copolymers*) are self-assembled into a variety of morphological structures depending upon the block copolymer concentration, PPO/PEO composition, temperature, and the presence of additives [13]. Pluronics' high surface activity, temperature-based micellization, and reversible thermo-rheological behaviour make them versatile materials with applications in the cosmetics, food, coatings, paints, petroleum, and pharmaceutical industries [14]. Pluronics act as stabilizing agents for MNPs by forming a protective layer around them. This prevents their aggregation, ensuring colloidal stability and preventing the nanoparticles from undergoing precipitation or agglomeration.

The amphiphilic nature of Pluronics allows for control over the size and morphology of MNPs. By adjusting the concentration, composition, and molecular weight of the Pluronic, researchers can influence the size and shape of nanoparticles, enabling the production of uniform and well-defined structures [15]. Pluronics are biocompatible and widely used in biomedical applications due to their non-toxic nature. Their amphiphilic structure also facilitates interactions with biological systems, making them suitable for drug delivery, imaging, and therapeutic applications. Pluronics offer versatility in synthesizing various types of MNPs (e.g., gold, silver, platinum) and allow fine-tuning of their properties, such as optical, catalytic, and magnetic characteristics, by controlling the Pluronic-nanoparticle interactions. The synthesis of MNPs using Pluronics is relatively straightforward and scalable, making it an attractive method for large-scale production [16].

To understand the importance of polymer mediated metal nanoparticles, the present research was aimed at developing and well-characterizing MNPs (specifically copper and silica NPs) using Pluronic polymers as stabilizing agents and/or reducing agents for various useful applications such as antimicrobial activity, dye degradation, CO<sub>2</sub> adsorption, and dye removal.

The structure of Pluronic polymers used in the present research work is shown in Figure 3 and their characteristic is listed in Table 1.



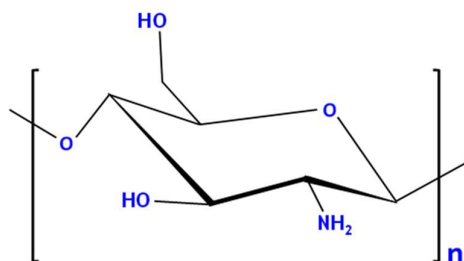
**Figure 3:** Molecular structures of Pluronic polymer ( $m = EO$ ,  $n = PO$ )

**Table 1:** Molecular properties of studied Pluronics.

Pluronics <sup>®</sup>	Mol.Wt. (g mol <sup>-1</sup> )	Composition	% PEO	CP of 1% (°C)	HLB
F127	12600	EO <sub>100</sub> PO <sub>65</sub> EO <sub>100</sub>	70	>100°	22
F88	11400	EO <sub>104</sub> PO <sub>48</sub> EO <sub>104</sub>	80	>100°	28
L64	2900	EO <sub>13</sub> PO <sub>30</sub> EO <sub>13</sub>	40	58°	14
L35	1900	EO <sub>11</sub> PO <sub>16</sub> EO <sub>11</sub>	50	73°	19
L121	4400	EO <sub>5</sub> PO <sub>70</sub> EO <sub>5</sub>	10	14°	1
P123	5750	EO <sub>20</sub> PO <sub>70</sub> EO <sub>20</sub>	30	90°	8

Not only that, the other polymer that has also been used in the present research is chitosan for the development of MNP composites. Chitosan, a biopolymer, can be produced from chitin.

Chitosan (shown in Figure 4) has desirable properties such as being nontoxic, having a high charge density, having reactive hydroxyl and amino groups, and having better hydrogen bonding capacity. These features of chitosan have made it an attractive material for various applications.



*Figure 4: Molecular structure of chitosan polymer*

The developed Pluronic mediated copper nanoparticles (CuNPs) have been evaluated for their antimicrobial applications as well as photocatalysts for common textile dye degradation. Other Pluronic mediated and chitosan-based silica nanoparticles (SiO<sub>2</sub>NPs) were studied for their potent applications in CO<sub>2</sub> adsorption and common dye removal.

In order to examine Pluronic mediated metal nanoparticles, a range of sophisticated characterization techniques were employed. Some of these were spectral, like FTIR, UV-Visible, and UV-Fluorescence spectroscopy; thermal, such as TGA and DTA; optical, like TEM and SEM; scattering, such as DLS, Zeta, and versatile XRD; and EDX spectroscopy. We also utilized the Brunauer-Emmett-Teller (BET) method for surface analysis. The synthesized Pluronic-mediated metal nanoparticles were evaluated in a series of studies, including antimicrobial activity, dye degradation, CO<sub>2</sub> adsorption, and dye removal.

*In order to meet all objectives, the contents of the present thesis are summarized into seven chapters.*

## **Chapter 1: General Introduction**

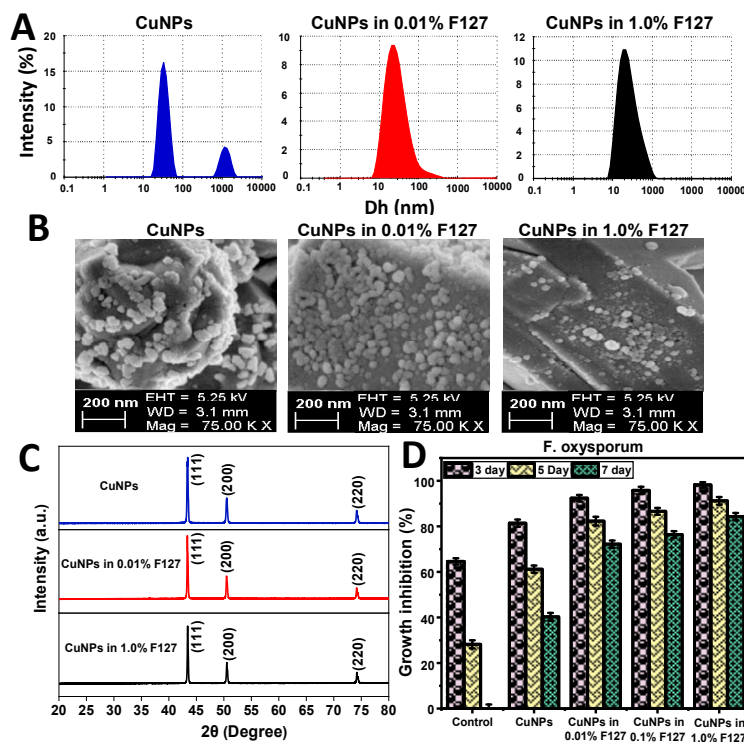
MNPs and polymer mediated MNPs and their applications have been reported using the most recent research relevant to this chapter. The introduction of Pluronic polymers and their role in the development of MNPs as stabilizing agents and reducing agents have been discussed. This chapter gives an organized overview of the important research results in the field of developing copper nanoparticles (CuNPs) and silica nanoparticles (SiO<sub>2</sub>NPs) using polymers.

## **Chapter 2: Materials and Characterization Methods**

The details of materials involved in the present research work, like Pluronics, chitosan, reducing agents, and precursors of MNPs, have been provided in this chapter. This chapter presents the basic profiles and calibration curves of various organic dyes used for dye degradation and removal studies. Various methods and techniques, along with their specifications, used in the present work will be shown in this chapter, along with their parameters for data evaluation.

### Chapter 3: Pluronic mediated copper nanoparticles for antimicrobial applications: Investigating the role of Pluronic concentration

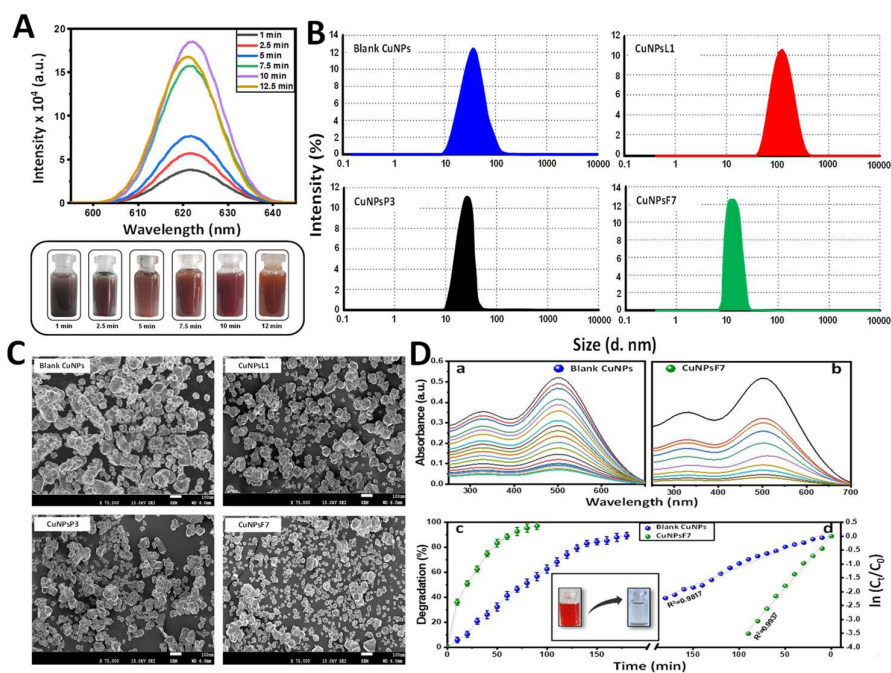
In this chapter, the development of copper nanoparticles (CuNPs) with antimicrobial activities shows high potential for various clinical applications. We herein synthesized Pluronic (F127) mediated CuNPs with improved oxidative stability using a simple process that included environment friendly Vitamin C (ascorbic acid) as a reducing agent and nontoxic F127 polymer as a stabilizing agent. To optimize the reducing agent, the effect of the molar ratio of ascorbic acid-to-Cu<sup>2+</sup> salt was investigated through fluorescence measurements. The synthesized F127 mediated CuNPs were characterized using UV-Vis, DLS, Zeta potential, XRD, FE-SEM, and also EDX analysis. The UV-Visible spectrum presented that the inclusion of F127 improved the efficiency of CuNPs synthesis. In addition, DLS demonstrated that when the concentration of F127 was increased, the particle size of CuNPs was reduced. According to the XRD patterns, all the CuNPs are fcc-structured and crystalline. The FE-SEM and EDX images indicated the cubic morphology and the absence of any oxides of copper. The synthesized CuNPs have different particle sizes, showing strong antimicrobial activities against Gram-negative and Gram-positive bacteria as well as fungi. Our findings suggest that F127 mediated CuNPs could be a new way to fight both human and plant pathogens [17].



**Figure 4:** (A) Size distribution curve of the blank and Pluronic mediated CuNPs at RT (B) FE-SEM images of the blank and Pluronic mediated CuNPs (C) X-ray diffraction patterns of the blank and Pluronic mediated CuNPs (D) Growth inhibition of the blank and Pluronic mediated CuNPs against *F. oxysporum* after 3 days, 5 days, and 7 days of incubation period.

## Chapter 4: Pluronic mediated copper nanoparticles as photocatalyst for dye degradation

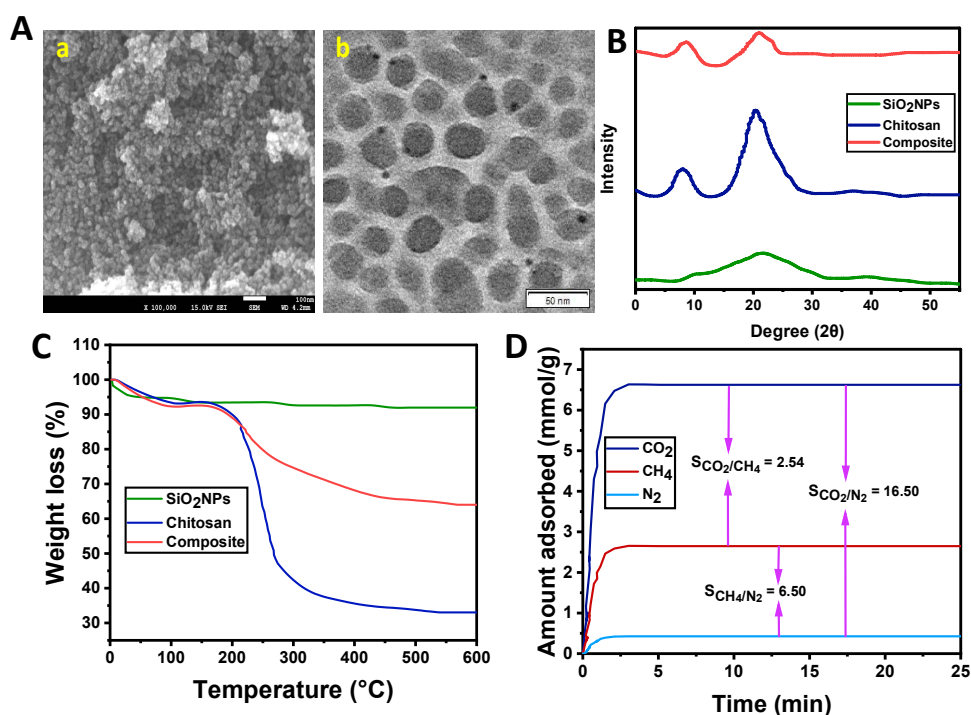
Pluronic-mediated copper nanoparticles (CuNPs) were fabricated using the reducing agent sodium borohydride in the micellar media of different Pluronic (L121, P123, and F127) using cost-effective microwave techniques. The microwave-irradiation used to create CuNPs has been optimized. All Pluronic-mediated CuNPs fabricated emit red light and have been thoroughly characterized using a range of advanced techniques. The results showed that the hydrophilic PEO and hydrophobic PPO parts of the Pluronic have a countable impact on the particle size and stability of the CuNPs. When compared to the other two Pluronic micellar media, the Pluronic F127 mediated CuNPs (CuNPsF7) performed better in terms of uniformity, size reduction, and stability. In this context, CuNPsF7 has been investigated as a powerful photocatalyst for the degradation of textile anionic (Congo red and methyl orange) and cationic (Methylene blue and rhodamine B) dyes. When compared to blank CuNPs, the results confirmed that the CuNPsF7 followed pseudo-first-order kinetics and significantly increased the rate and efficiency of dye degradation. In conclusion, the Pluronic-mediated CuNPs serve as potent photocatalysts to remove organic dyes in the treatment of waste water from textile industries [18].



**Figure 5:** (A) Fluorescence spectra of the blank CuNPs fabricated at various microwave- irradiation time and color alteration during the fabrication of CuNPs (B) Size distribution curves of blank CuNPs and Pluronic-mediated CuNPs dispersions (C) FE-SEM images of the CuNPs and Pluronic-mediated CuNPs (D) (a) UV-Vis spectra of CR dye degradation using blank CuNPs, (b) UV-Vis spectra of CR dye degradation using CuNPsF7, (c) % Degradation comparison of CR dye, (d) Kinetic study of photodegradation of CR (Insert image indicates the CR dye)

## Chapter 5: Pluronic mediated silica nanoparticles with chitosan as composite for CO<sub>2</sub> adsorption

In this chapter, peanut shell ash (PSA) was used for the synthesis of SiO<sub>2</sub>NPs with mediation of Pluronic polymer. Here various types of Pluronic were used as stabilizers and size-controlling agents during the preparation process. Mesoporous chitosan-SiO<sub>2</sub>NPs composite. The prepared nanoparticles and composite were characterized using DLS, Zeta potential, TEM, FTIR, XRD, TGA, EDX, and BET. From the TEM micrograph, composite had a sphere-like, uniformly distributed surface. The average size of composite was 18 nm which was confirmed by TEM. The mesoporous structure of composite was characterized with N<sub>2</sub> adsorption and desorption measurements. We evaluated CO<sub>2</sub> adsorption using a volumetric method. Composite showed a maximum CO<sub>2</sub> adsorption capacity and a high selective separation capacity for CO<sub>2</sub>/N<sub>2</sub>. We discussed the impact of amines on carbon dioxide adsorption. Stable CO<sub>2</sub> adsorption and desorption were confirmed after 10 cycles of experiments. Therefore, composite exhibit great potential for CO<sub>2</sub> capture.

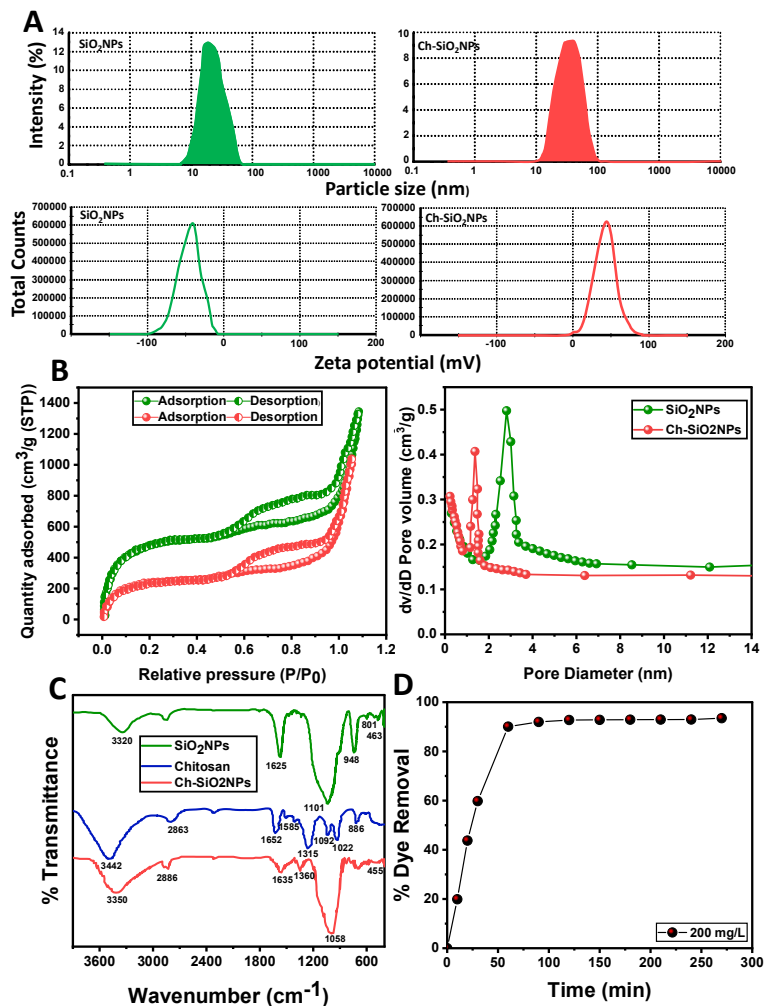


**Figure 6:** (A)(a) FE-SEM image of the composite and (b) TEM image of the composite (B) XRD patterns of the SiO<sub>2</sub>NPs, Chitosan and composite. (C) TGA spectra of SiO<sub>2</sub>NPs, chitosan and composite (D) Selective separation of CO<sub>2</sub>/N<sub>2</sub> isotherms

## Chapter 6: Pluronic mediated silica nanoparticles with chitosan as composite for the dye removal

Silica nanoparticles (SiO<sub>2</sub>NPs) from renewable sources can be utilized in various materials, including paints, fuel cell membranes, Li-ion batteries, adsorbents, and catalysts. This study explores a method for producing very pure SiO<sub>2</sub>NPs from peanut shell ash (PSA) with mediation of Pluronic polymer. Chitosan was deposited on fumed silica without crosslinkers

or activators to prepare Ch-SiO<sub>2</sub>NPs. Chitosan surface layer has high affinity for organic molecules like congo red dye and is robust to a wide range of simulated conditions (temperature, time, solute concentration). They were used as an adsorbent material to remove Congo red dye from aqueous solutions. The Generalized Langmuir (GL) equation was used to analyze experimental equilibrium data with the adsorption system's energetic heterogeneity. The temperature effect on dye uptake and adsorption was examined. According to studies on the impact of temperature on adsorption equilibrium, the maximum adsorption capacity of synthesized Ch-SiO<sub>2</sub>NPs composite towards Congo red is about 2.5 times faster for 50°C than 10°C. The SiO<sub>2</sub>NPs and Ch-SiO<sub>2</sub>NPs were characterized using various techniques, including DLS, zeta potential, EDX, TEM, X-ray diffraction, surface area, pore distribution, FTIR, and TGA analyses. The Ch-SiO<sub>2</sub>NPs adsorbent could be reused up to six times after congo red adsorption, which was excellent. The results show that PSA waste material can be used to produce highly pure nanosilica adsorbents with high adsorption capacity and reuse potential.



**Figure 7:** (A) (a) Size distribution curves (b) Zeta potential profile (B) (a) N<sub>2</sub> adsorption adsorption-desorption isotherms and Pore size distributions. (C) FTIR spectra of SiO<sub>2</sub>, chitosan and Ch-SiO<sub>2</sub>NPs (D) The effect of time on the removal of CR dye by Ch-SiO<sub>2</sub>NPs adsorbent. Conditions: 25 °C, initial concentration: 200 mg/L, and adsorbent mass: 0.5 g

## Chapter 7: Summary and Conclusions

The thesis ends with a summary of all the reported work and general conclusions drawn from the investigations.

### References:

1. Heiligtag, F.J. and Niederberger, M., **2013**. The fascinating world of nanoparticle research. *Materials today*, 16(7-8), pp.262-271.
2. De, M., Ghosh, P.S. and Rotello, V.M., **2008**. Applications of nanoparticles in biology. *Advanced Materials*, 20(22), pp.4225-4241.
3. Jamkhande, P.G., Ghule, N.W., Bamer, A.H. and Kalaskar, M.G., **2019**. Metal nanoparticles synthesis: An overview on methods of preparation, advantages and disadvantages, and applications. *Journal of drug delivery science and technology*, 53, p.101174.
4. Talapin, D.V. and Shevchenko, E.V., **2016**. Introduction: nanoparticle chemistry. *Chemical Reviews*, 116(18), pp.10343-10345.
5. Shnoudeh, A.J., Hamad, I., Abdo, R.W., Qadumii, L., Jaber, A.Y., Surchi, H.S. and Alkelany, S.Z., **2019**. Synthesis, characterization, and applications of metal nanoparticles. In *Biomaterials and bionanotechnology* (pp. 527-612). Academic Press.
6. Pal, J. and Pal, T., **2015**. Faceted metal and metal oxide nanoparticles: design, fabrication and catalysis. *Nanoscale*, 7(34), pp.14159-14190.
7. Zhu, Q.L. and Xu, Q., **2016**. Immobilization of ultrafine metal nanoparticles to high-surface-area materials and their catalytic applications. *Chem*, 1(2), pp.220-245.
8. Shifrina, Z.B., Matveeva, V.G. and Bronstein, L.M., **2019**. Role of polymer structures in catalysis by transition metal and metal oxide nanoparticle composites. *Chemical reviews*, 120(2), pp.1350-1396.
9. Sarkar, S., Guibal, E., Quignard, F. and SenGupta, A.K., **2012**. Polymer-supported metals and metal oxide nanoparticles: synthesis, characterization, and applications. *Journal of Nanoparticle Research*, 14, pp.1-24.
10. Rozenberg, B.A. and Tenne, R., **2008**. Polymer-assisted fabrication of nanoparticles and nanocomposites. *Progress in polymer science*, 33(1), pp.40-112.
11. Bodratti, A.M. and Alexandridis, P., **2018**. Amphiphilic Block Copolymers in Drug Delivery: Advances in Formulation Structure and Performance. *Expert Opinion on Drug Delivery*, 15(11), pp.1085-1104.
12. Shaikh, S.J., Patel, H.S. and Sharma, R.K., **2020**. Self-assembly of PEO-PPO-PEO Block Copolymers: Advanced Nanosystems for Drug Delivery Applications. *Advances in Nanotechnology*, Ch. No. 5, NOVA Science Publishers, USA. 24, pp. 175-204.
13. Alexandridis, P., Holzwarth, J.F. and Hatton, T.A., **1994**. Micellization of Poly (ethylene oxide)-Poly (propylene oxide)-Poly (ethylene oxide) Triblock Copolymers

- in Aqueous Solutions: Thermodynamics of Copolymer Association. *Macromolecules*, 27(9), pp.2414-2425.
14. Alexandridis, P. and Hatton, T.A., **1995**. Poly (ethylene oxide)-Poly (propylene oxide)-Poly (ethylene oxide) Block Copolymer Surfactants in Aqueous Solutions and at Interfaces: Thermodynamics, Structure, Dynamics, and Modeling. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 96(1-2), pp.1-46.
  15. Alexandridis, P. and Tsianou, M., **2011**. Block copolymer-directed metal nanoparticle morphogenesis and organization. *European Polymer Journal*, 47(4), pp.569-583.
  16. Sokolsky-Papkov, M. and Kabanov, A., **2019**. Synthesis of well-defined gold nanoparticles using pluronic: The role of radicals and surfactants in nanoparticles formation. *Polymers*, 11(10), p.1553.
  17. Patel, S.S., Patel, H.S., Kunjadiya, A., Rao, V. and Sharma, R.K., **2022**. Synthesis, Characterization and Antimicrobial Activity of Poloxamer-Assisted Copper Nanoparticles: Investigating the Effects of Different Concentrations of Poloxamer 407. *ChemistrySelect*, 7(31), p.e202201477.
  18. Patel, S.S. and Sharma, R.K., **2023**. Facile fabrication of Pluronic-mediated copper nanoparticles using microwave techniques and their application as the photocatalysts for various organic dyes degradation. *Materials Today Communications*, 37, p.106990.

## ❖ List of the Research Publications

### Under the Thesis work

- 1) Patel, S.S., Patel, H.S., Kunjadiya, A., Rao, V. and Sharma, R.K., **2022**. Synthesis, Characterization and Antimicrobial Activity of Poloxamer-Assisted Copper Nanoparticles: Investigating the Effects of Different Concentrations of Poloxamer 407. *ChemistrySelect*, 7(31), p.e202201477. [doi.org/10.1002/slct.202201477](https://doi.org/10.1002/slct.202201477)
- 2) Patel, S.S. and Sharma, R.K., **2023**. Facile fabrication of Pluronic-mediated copper nanoparticles using microwave techniques and their application as the photocatalysts for various organic dyes degradation. *Materials Today Communications*, 37, p.106990. [doi.org/10.1016/j.mtcomm.2023.106990](https://doi.org/10.1016/j.mtcomm.2023.106990)

## ❖ List of the Papers presented in the Conferences/Seminars/Workshops

- 1) Poloxamer-assisted copper nanoparticles: Synthesis, characterization and antimicrobial activity.  
**Saurav S Patel**, Anju Kunjadiya, and Rakesh K Sharma., at International Seminar on Advanced Materials and Applications-2022 (ISAMA-2022), Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara (18<sup>th</sup> July, 2022) (**Oral-Third Prize**).

- 2) Fabrication of Pluronic mediated copper nanoparticles using microwave technique and their catalytic application for the degradation of various organic dyes.  
**Saurav S. Patel** and Rakesh K. Sharma., at National Conference on Modern Evolution in Material & Chemical Sciences (MEMCS-23), Parul university (6, 7 January, 2023) (**Oral**).
- 3) Chitosan-based Silica Nanoparticles Derived from Peanut Waste Ash as The Sustainable Hybrid Biosorbents for Removal of Congo Red Dye from Textile Effluent: Study on Influence of Adsorption Equilibrium and Kinetics.  
**Saurav S. Patel** and Rakesh K. Sharma., at National Conference on Emerging Technologies in Chemistry & their Applications (NCETCA-23), Government College Sirohi, Rajasthan (19, 20 October, 2023) (**Poster**).

### **Participated**

- 1) International Conference on “Surface Chemistry: Colloids and Interface Aspects with Applications (SCCIA-2022), Department of Chemistry, Sardar Vallabhbhai National Institute of Technology (SVNIT), Gujarat – INDIA (3-7 January, 2022).
- 2) National Webinar on Nanostructured Materials Based on Surfactants: Micelles, Microemulsion, Foams and Hydrogel, Department of Chemical Engineering, SAL College of Engineering, Ahmedabad (10 February, 2021).
- 3) International Conference on 9<sup>th</sup> Asian Network for Natural & Unnatural Materials (Annum-9) 2022, Department of Chemistry, University of Delhi (8 April, 2022).
- 4) National webinar lecture series on Recycling of Plastic Waste to Plastic Composites Products, Asian Polymer Science, (10 April, 2021).
- 5) National level GUNI SKPCP Alumni Glory-Talk Series on Medical Chemistry & Quality Assurance: Pillars for Drug Development and Product Quality, Shree S. K. Patel College of Pharmaceutical Education & Research, Ganpat University (24-25 April, 2021).
- 6) International Conference on Smart materials: Application to Devices, Department of Physics and Department of Electronics Kamla Nehru Mahavidyalaya, Nagpur (17-18 May, 2021).
- 7) International Conference on Recent Advances in Chemical, Physical and Biological Sciences, Department of chemistry, Nabira Mahavidyalaya, Katol and Association of Chemistry Teachers (ACT), C/o Homi Bhabha Centre for Science Education (TIFR) Mumbai (29-30 June 2021).
- 8) International Conference on Sustainable and Futuristic Materials, International Research Centre and Department of Chemistry, Kalasalingam Academy of Research and Education, Krishnakoli, Department of Chemistry, J. M. Patel Arts, Commerce and Science College, Bhandara & Department of Chemistry, Kamla Nehru Mahavidyalaya, Nagpur (29-30 November, 2021).

- 9) National Symposium in Chemistry “ANKURAN 2022” Exploring New Dimensions in Chemistry, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore (28 September, 2022).

### **Workshops**

- 1) Two Days National e-Workshop on Spectral Data Interpretation for Structure Elucidation of Simple Organic Compounds, Shree S. K. Patel College of Pharmaceutical Education & Research, Ganpat University (26-27 March, 2021).
- 2) National level One week faculty development programmed on research methodology organized, Amar Sewa Mandal’s Kamla Nehru Mahavidyalaya, Nagpur (26 April - 1 May, 2021).
- 3) National level Workshop on “How to Write and Publish”, Department of Commerce and management, Truba Group of Institute, Bhopal, Madhya Pradesh, affiliated to Barkatullah University in Technical collaborated with The Global association of Social Science, The International Research journal of Social Science and Humanities, (6, 7 May, 2021).
- 4) Three Days National Online FDP on ICT Tool For Effective Teaching Learning, IQAC, Amar Sewa Mandal’s Kamla Nehru Mahavidyalaya, Nagpur (8-10 June, 2021).
- 5) One week training programmed on R&D Equipment on the theme characterization of materials/compound using advanced instruments, CRF IIT Delhi & NIT Warangal (11-17 April, 2023)

**Signature of Candidate**

**(Patel Saurav S.)**

Endorsement of Supervisor;  
Synopsis is approved by me

**Dr. Rakesh K. Sharma**  
**Guide**

**Head**  
**Applied Chemistry Department**

**Dean**  
**Faculty of Technology and Engineering**