SYNOPSIS

Of the Thesis Entitled

"INVESTIGATION ON GRAPHENE BASED COMPOSITES OF METAL OXIDES FUNCTIONALIZED BY SURFACTANTS"

To be Submitted to

The Maharaja Sayajirao University of Baroda

For the Degree of

Doctor of Philosophy

In

Applied Chemistry

By

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Under the Supervision of

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Name of the Candidate	Chavda Vishwajit Ranjitsinh
Subject	Applied Chemistry
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Title of Thesis	"INVESTIGATION ON GRAPHENE BASED COMPOSITES OF METAL OXIDES FUNCTIONALIZED BY SURFACTANTS"
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"INVESTIGATION ON GRAPHENE BASED COMPOSITES OF METAL OXIDES FUNCTIONALIZED BY SURFACTANTS"

The last 4-5 decades witnessed a sharp increase in the fundamental progress and prospects of various kinds of materials such as nanomaterial, electronic material, solvent material, associated material, membrane material, and porous material among others. Among these materials, carbon allotropes find special attention due to their novel properties and potential application in various fields of life. Graphene is the most sought carbon allotrope used as pure and its daughter components or composites in the frontiers of science and engineering research. Graphene is an aromatic hydrocarbon with sp^2 hybridization. It is a naturally thin, hexagonal two-dimensional (2D) carbon chain sheet [1,2].

Graphene-based composites have been successfully made with inorganic nanostructures [3], organic crystals[4], polymers[5], metal–organic frameworks (MOFs)[6], biomaterials[7], and carbon nanotubes (CNTs)[8], and are intensively explored in applications such as batteries[9], supercapacitors[10], fuel cells[11], photovoltaic devices[12], photocatalysis[13], sensing platforms[7] Raman enhancement [14] and so on.

Dye pollution is one of the most challenging problems faced by the textile finishing, dye manufacturing, and pulp and paper industries. The discharge of harmful dyes to rivers without proper treatment causes damage to the environment, including biota, both aquatic and terrestrial. Removal of water-soluble dyes from water is a big challenge. There are many techniques to remove dyes from wastewater including physical, biological, and chemical methods. Although chemical and biological methods provide high dye removal efficacy, they generate material that requires further treatment [15]. In physical methods, adsorption is one of the most popular techniques to recycle contaminated water. Moreover, modification of the adsorbents improves potential efficacy towards several pollutants. The surfactant-treated adsorbent has been found one such effective modification. Cationic surfactant has recently been used to modify amphiphilicity of the adsorbent surfaces [16]. DES is now gaining momentum as a potential modifier in the nanomaterial synthesis, processing, and functionalization of NCs [17]. These materials are safe, accessible, green, and environmentally friendly, and show increased affinity towards materials of interest.

In the last decades, fluorescent chemo-sensors have been preferred over other conventional analytical tools due to their better sensitivity and selectivity [18]. The photophysical behavior of dyes in deep eutectic solvent (DES) has garnered considerable attention. Understanding the modulation of dyes' photophysical properties in DES is crucial for the development of novel functional materials and applications in areas such as sensing, optoelectronics, and energy conversion. Furthermore, the addition of specific additives to DES can further enhance or alter the photophysical properties of dyes, offering new avenues for tailoring their optical behavior in these solvents [19].

Fossil fuels, including oil, natural gas, and coal, along with their derivatives, currently meet the majority of the world's energy needs. Polymer blend nanocomposites have emerged as promising materials for the separation and purification of gases in various applications[20]. These nanocomposites combine the advantages of both polymers and nanoparticles, offering enhanced gas separation performance, improved mechanical properties, and increased chemical stability. By incorporating nanoparticles into polymer blends, the selectivity and permeability of the resulting nanocomposites can be finely tuned, enabling efficient separation of different gas mixtures. This capability holds great potential in applications such as gas storage, natural gas purification, carbon dioxide capture, and hydrogen purification. The design and development of polymer blend nanocomposites for gas separation offer a pathway towards sustainable and efficient gas processing technologies with reduced energy consumption and environmental impact[21].

Nanocomposites have demonstrated promising properties in terms of antioxidant, antimicrobial, and photocatalytic activity. The incorporation of nanoparticles with high antioxidant capabilities into a matrix material enhances the overall scavenging ability, protecting against oxidative stress and promoting cellular health. Moreover, nanocomposites exhibit potent antimicrobial activity due to the intrinsic properties of nanoparticles, effectively inhibiting the growth and proliferation of pathogenic microorganisms. Additionally, the photocatalytic behavior of nanocomposites enables the degradation of organic pollutants and the generation of reactive oxygen species under light irradiation, leading to environmental remediation and energy conversion. The investigation and understanding of the antioxidant, antimicrobial, and photocatalytic properties of nanocomposites hold significant potential for a wide range of applications, including biomedical devices, water purification systems, and energy technologies [22].

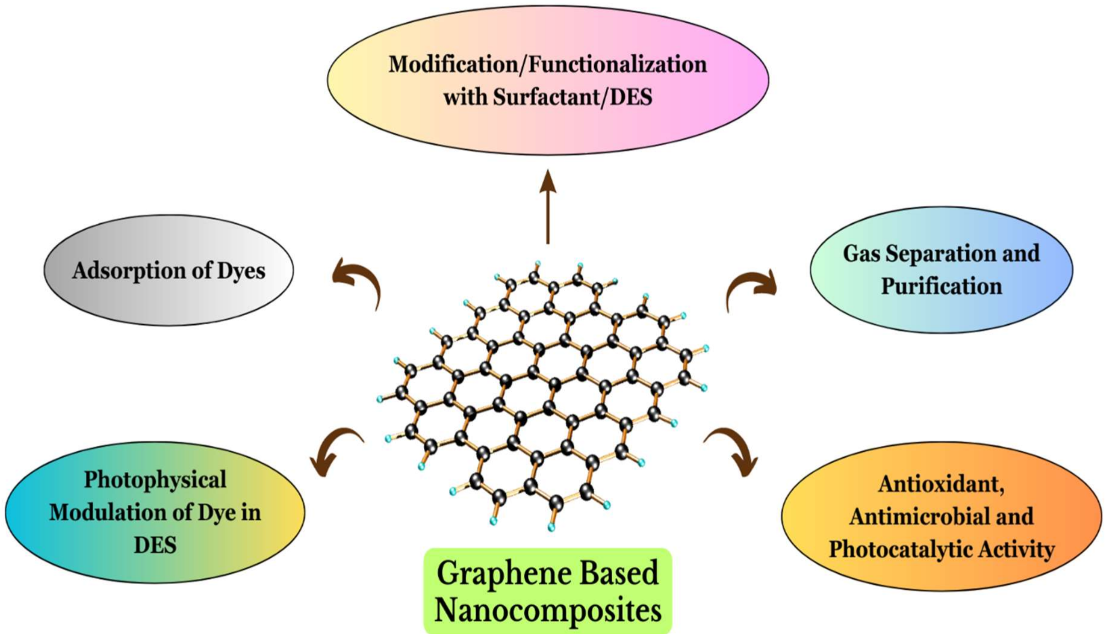


Fig.1: Various studies conducted on graphene-based nanocomposites

Summary of Research Work:

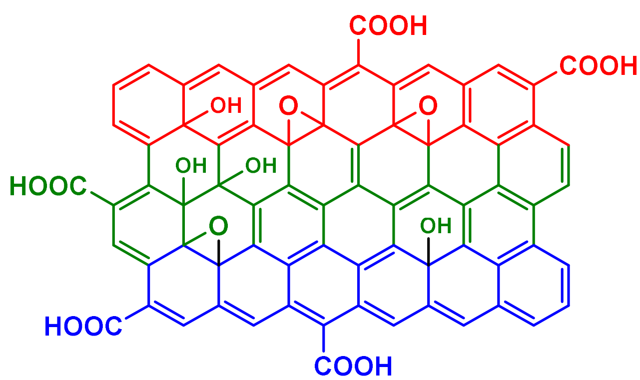
The Thesis will be presented in the form of the eight following chapters:

Chapter-1	General Introduction
Chapter-2	Materials, Synthesis, and Structural Characterization of Graphene Based Metal Oxides
Chapter-3	Functionalization/Modification of Nanocomposites with Surfactants/Deep Eutectic Solvents and Structural Characterization
Chapter-4	Adsorption of Dyes using Surfactants/Deep Eutectic Solvents Modified Nanocomposites
Chapter-5	Photophysical Modulation of Dyes in Deep Eutectic Solvents with or without Additives
Chapter-6	A Polymer Blend Nanocomposites for the Separation and Purification of Gases for Different Applications
Chapter-7	Antioxidant, Antimicrobial, and Photocatalytic Activity of the Nanocomposites
Chapter-8	Conclusions and Future Work

Chapter-1: Introduction

This chapter of the thesis provides a bird's-eye view of a general introduction, a brief historical background, and fundamental aspects of graphene nanocomposites. The chapter focuses on the role of surfactants and deep eutectic solvents in the modification/functionalization of graphene-based nanocomposites. These nanocomposites are further utilized in various applications. The chapter systematically highlights the most critical and relevant research findings in this field of work.

The direct observation and characterization of a mechanically exfoliated graphene monolayer by Novoselov et al. in 2004[23] have sparked the exponential growth of graphene research in both the scientific and engineering communities. Graphene, a single-layer carbon sheet with a hexagonal packed lattice structure, has shown many unique properties, such as the quantum hall effect (QHE), high carrier mobility at room temperature (~10 000 $cm^2 V^{-1} s^{-1}$)[23] large theoretical specific surface area (2630 $m^2 g^{-1}$)[24], good optical transparency (~97.7%)[25], high Young's modulus (~1 TPa) and excellent thermal conductivity (3000–5000 $W m^{-1} K^{-1}$)[26]. To further exploit these properties in various kinds of applications, versatile and reliable synthetic routes have been developed to prepare graphene and its derivatives, ranging from the bottom-up epitaxial growth to the top-down exfoliation of graphite by means of oxidation, intercalation, and/or sonication. In the last few decades, huge efforts have been made to synthesize inorganic nanostructures with controlled shape, size, crystallinity and functionality. These materials are widely employed in applications like adsorption, photocatalytic, electronics, optics, electrochemical energy conversion and storage, solar energy harvesting, and so on.



Graphene Oxide

The term surfactant is a blend of surface active agent. They are usually organic compounds and their unique molecular structure contains two opposite groups. One is a hydrophobic group/part (“tail”) usually a straight hydrocarbon chain while the other is a hydrophilic group (“head”), ionic/polar in nature [27]. On the basis of charge on the polar head group, surfactants can be classified into different groups namely,

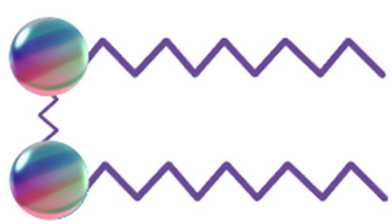
- *Cationic surfactant:* CTAB, DTAB, TTAB

- *Anionic surfactant:* SDS, SDBS

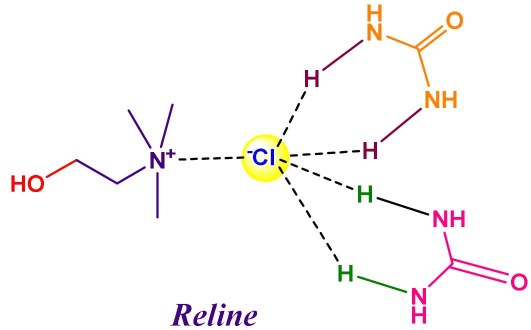
- *Zwitterionic surfactant:* Lauryl betaine, Cocamidopropyl betaine

- *Nonionic surfactant:* Triton X-100, Tween 80

- *Gemini surfactant:* CGS 16-4-16



Based on molecular structures surfactants are also divided into various classes such as Gemini surfactants, bola form amphiphiles, block copolymers, and biosurfactants among others. A spacer forms a chemical link between two conventional surfactant molecules to form a Gemini surfactant. Gemini surfactants potentially aggregate at much lower concentrations and have superior surface properties than ordinary surfactants [28].



DESs are originally recognized as a subclass of ILs because they have many similar basic properties, such as high thermal stabilities, low volatility, low vapor pressures, and flexible polarity. Abbot observed drastic depression in the melting point, of the mixture (DES, e.g., 'reline'), on judicious mixing of so-called hydrogen bond acceptor (HBA, e.g., choline chloride, ChCl) and hydrogen bond donor (HBD, e.g., urea). The solvent properties of DES can be exploited to dissolve carbon dioxide, metal oxides, natural and synthetic drugs, and dyes [29].

Chapter-2: Materials, Synthesis, and Structural Characterization of Graphene Based Metal Oxides

- **Materials**

Zirconium acetate [$Zr(CH_3COO)_2$] (99%, extra pure); Potassium permanganate ($KMnO_4$; 99%, AR); Hydrogen peroxide (H_2O_2; 30%, AR); are purchased from Loba Chemie, India. Choline chloride (99%, AR) and urea (99%, AR) has been obtained from TCI Chemicals, India. Zinc oxide (ZnO) nanoparticles (99%, APS-30-50 nm); Titanium dioxide (TiO_2) nanoparticles (99%, APS:30-50 nm); Silicon dioxide (SiO_2) nanoparticles (99%, APS:30-50 nm) are purchased from Platonic Nanotech Private Ltd., Jharkhand, India used after calcination for 6 h at 450°C. Cationic gemini surfactant (CGS), butanediyl-1,4, bis (N, N-hexadecyl ammonium) dibromide (16-4-16) has been synthesized and characterized as reported earlier. Rhodamine B (RB) (99%, microscopic grade), Methylene blue (MB) (99%, microscopic grade), and Congo red (99%, microscopic grade) are purchased from Loba Chemie, India. Surfactants have been obtained from Sigma Aldrich (99%, AR). The distilled water of specific conductance ~1 μS cm^{-1}.

- **Synthesis/experimental section**

Synthesis of Graphene oxide:

Graphene oxide (GO) was synthesized using a modified Hummer method, involving the exfoliation of graphite in the presence of strong acids and oxidants [30].

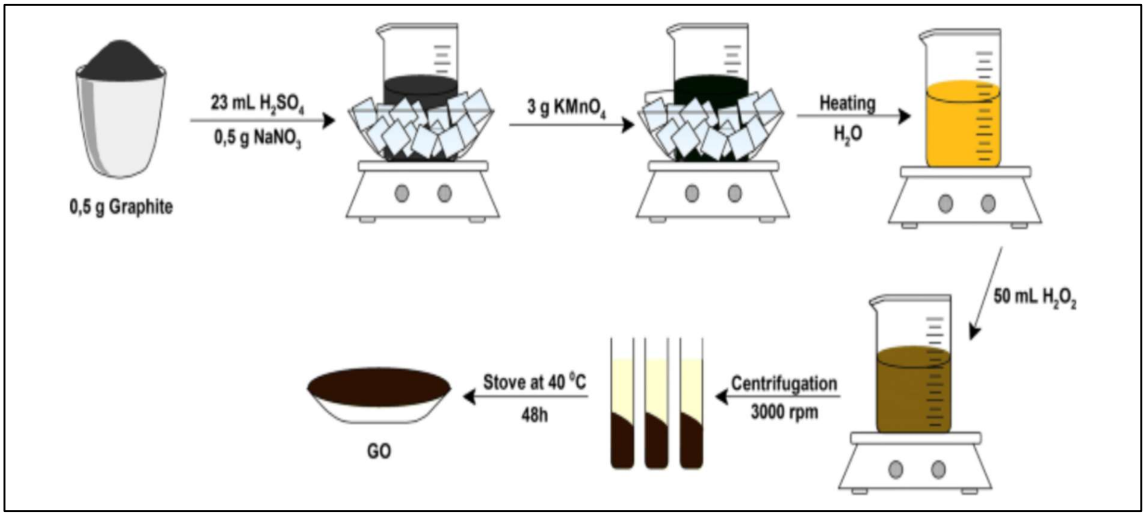


Fig.2: ***Synthesis of GO***

Synthesis of GO@ZrO$_2$:

Synthesis of nanocomposite, GO@ZrO_2 involved the following steps: Initially, GO was dispersed in an aqueous solution (1 g in 100 ml) through sonication for 30 m. The resulting dispersion was then stirred with an aqueous solution of Zirconium acetate (1 g in 100 ml) for 30 m. Subsequently, the mixture underwent another round of sonication for 1 h, followed by the gradual addition of 20 ml of 1M NaOH. The resulting mixture was heated to 100±0.1°C while being continuously stirred (2 h). A color change from greenish yellow to black indicated the formation of the dispersed aqueous GO@ZrO_2 nanocomposite. The black dispersed solution was filtered, and the solid mass was washed with ethanol and then distilled water (50 ml every 3 times). Finally, the GO@ZrO_2 nanocomposite was obtained as a black shiny powder after drying in a vacuum oven at 100±0.5°C for 12 h.

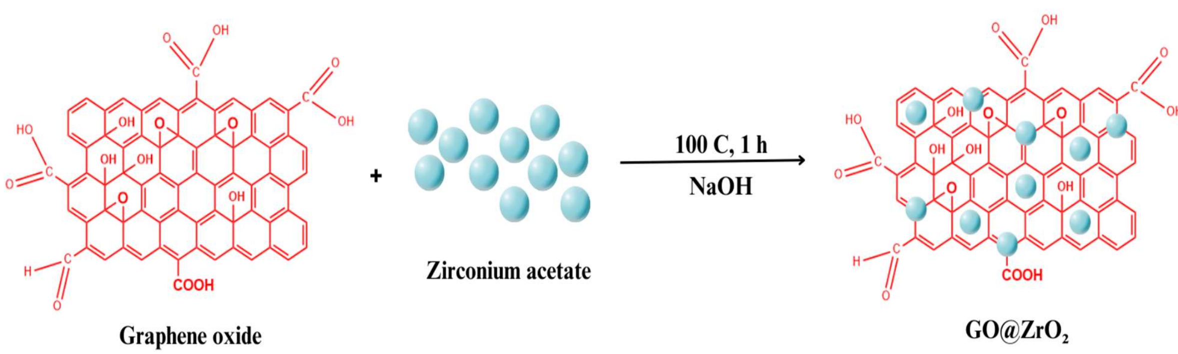


Fig.3: ***Synthesis of GO@ZrO$_2$***

Synthesis of GO@TiO_2, GO@ZnO, GO@SiO_2:

Metal oxide nanoparticles are calcinated for 6 h at 450°C. As discussed above we have synthesized graphene-metal oxide nanocomposites.

- **Characterization**

The structural, functional, morphological, optical, and thermal properties of synthesized nanocomposite were performed using XRD, FTIR, TGA, SEM-EDX, and TEM techniques respectively.

Chapter-3: Functionalization/Modification of Nanocomposites with Surfactants/Deep Eutectic Solvents and Structural Characterization

- **Modification of Graphene-Metal oxide using surfactant**

Synthesized GO@ZrO_2 has been modified by surfactants using the following procedure. GO@ZrO_2 (3 g/100 mL) has been stirred in aqueous CGS solution (0.1 g/100 ml). The resulting mixture was sonicated for 5 m and then gently stirred for another 2 h at room temperature. The resulting dispersion was subsequently centrifuged (3000 rpm for 10 m) and washed thrice with distilled water (50 ml each time). This gives CGS-modified NC (CGS-GO@ZrO_2) after drying in a vacuum oven at 65±0.5°C for 12 h.

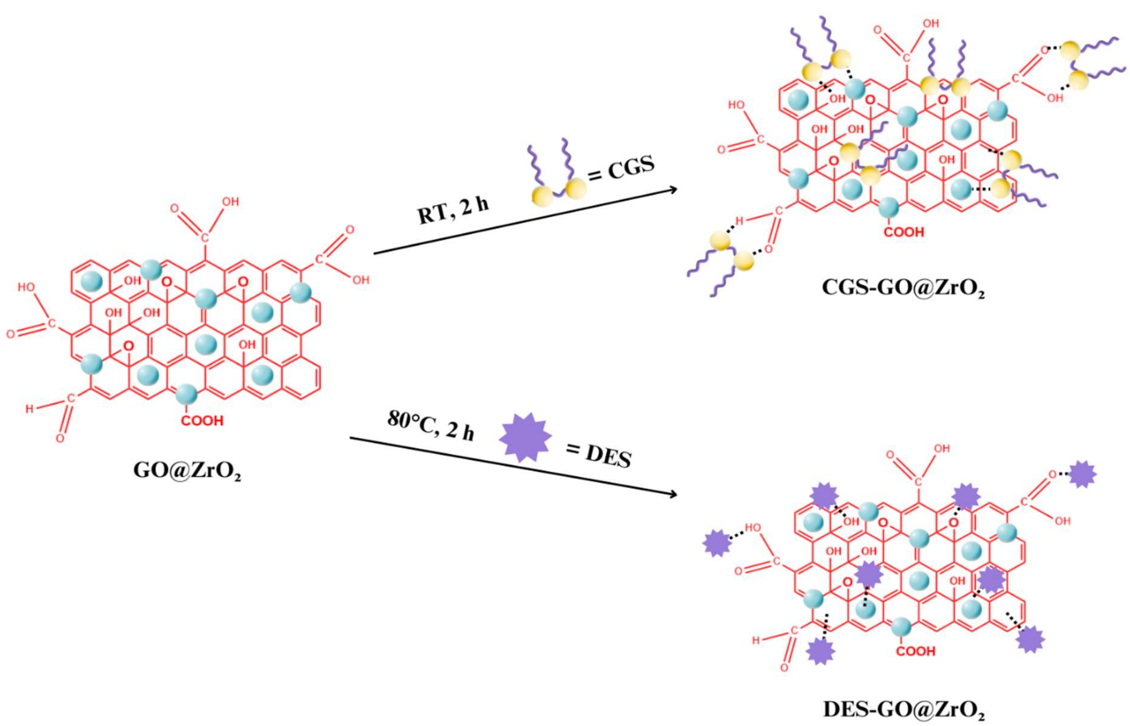


Fig.4:* *Synthesis of surfactant/DES modified nanocomposites

➢ Modification of Graphene-Metal oxides using DESs

DES was synthesized and characterized using the same procedure as previously reported[29]. Briefly, dried ChCl and urea (1:2 M ratio) were mixed and heated at 80±0.1°C with continuous stirring (~2h) till the appearance of clear fluid. This fluid was equilibrated for 24 h (in a vacuum oven) at 40±0.5°C.

1 g of $GO@ZrO_2$ was sonicated with 10 ml of DES for 30 m to get homogenous dispersion. This dispersion has been transferred in a round bottom flask and then stirred at 80±0.1°C for 2 h. The mixture was filtered and washed several times with distilled water followed by ethanol (50 ml every time). This DES-modified nanocomposite (DES-$GO@ZrO_2$) was dried in a vacuum oven for 24 h at 80±0.5°C.

➢ Characterization

The structural, functional, morphological, optical, and thermal properties of synthesized nanocomposite were performed using XRD, FTIR, TGA, SEM-EDX, and TEM techniques respectively.

Chapter-4: Adsorption of Dyes using Surfactants/Deep Eutectic Solvents Modified Nanocomposites

Dyes are well-known industrially important coloring material, that has been used as a model adsorbate to investigate its adsorption/removal from aqueous solution by modified nanocomposites. Adsorption variables were optimized in the light of [NC], [Dye], pH, and contact time.

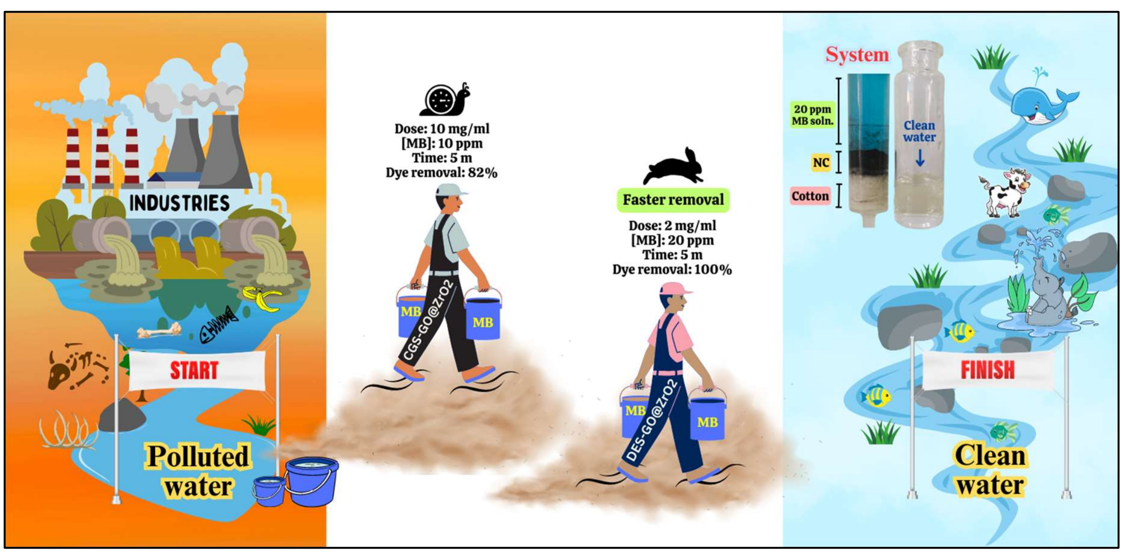


***Fig.5:* Graphical representation of dye adsorption using nanocomposites.**

➢ Dye Adsorption Study

The concentration of dyes has been quantified using an external calibration method. The solution of dye (20 ml) of an appropriate concentration (10-1000 mg L^{-1}) was mixed with different composite dosages (1-15 mg/ml) in quick-fit glass bottles. The mixture was kept under ambient conditions for different periods of time depending upon the nature of the study (adsorption or kinetics). The equilibrated (after the stipulated interval) mixture was centrifuged before UV-vis investigation (UV-1800, Shimadzu, Japan).

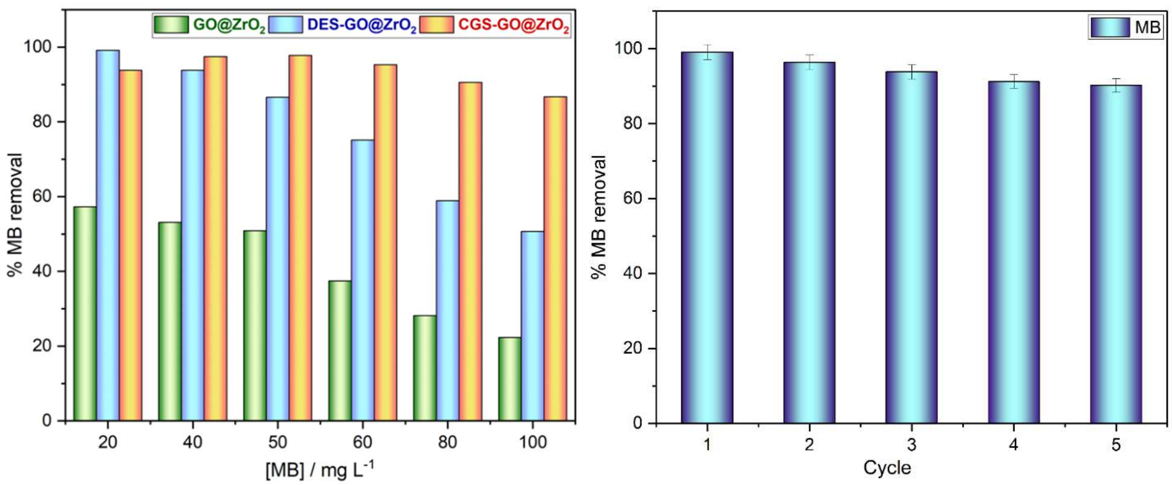


***Fig.6:* Dye adsorption and re-adsorption study on nanocomposites**

➢ Dye re-adsorption Study

The adsorbed dye has been separated from the adsorbent by washing (3 times) with 50 ml ethanol each time. With each washing, the adsorbent was filtered. The washed adsorbent was then dried in a vacuum oven at 80°C for 12 h. The so-obtained recharged nanocomposites have been used (up to the 5^{th} cycle) for the re-adsorption of dye.

Chapter-5: Photophysical Modulation of Dyes in Deep Eutectic Solvents with or without Additives

Photophysical behaviour of dye in deep eutectic solvents (DES, formed by quaternary ammonium salt and hydrogen bond donor (HBD) in a specific eutectic ratio) with or without graphene oxide (GO) or ionic surfactants is less known[19]. Effects of GO, surfactant, or GO + surfactant, in controlling dye movement, at various sites (GO surface, surfactant micelle, DES surface, or background solvent), have been fluorometrically reported. The findings of the work have implications in searching potential fluorescent levels/sensors for photophysics, photobiology, or wider vehicle range for sustained drug delivery.

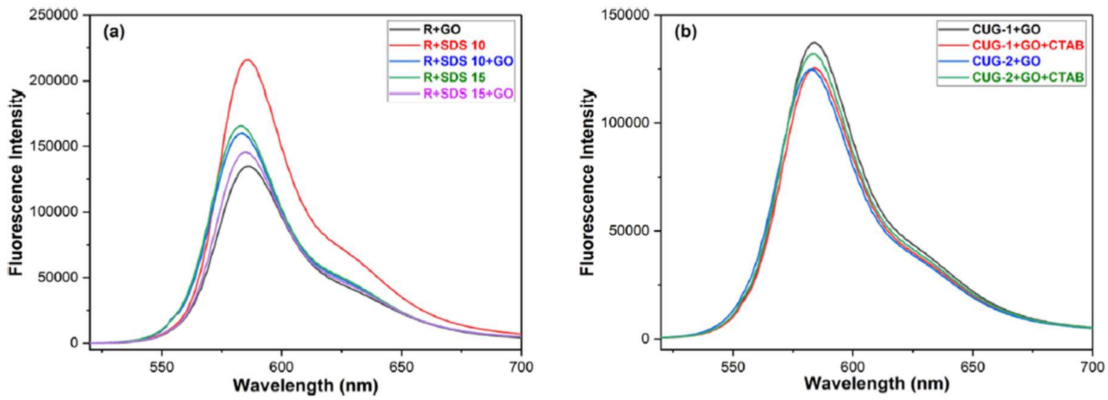


***Fig.7:* Emission spectra of RB with and without GO in different surfactants**

Studies allow us to conclude that RB fluorescence can be significantly modulated both in the presence of a surfactant or GO. Data show that a combined presence of GO and SDS (< CMC) enhances RB fluorescence ~ 1.6 times more than in pure reline. Our finding is different from the well-known surfactant micelle effect in water, where RB fluorescence was enhanced. Probably, the basic nature of reline produces zwitter ion which can form ion pair with DS^- monomer and restrict its interaction to GO surface as well as to Cl^- part of reline (due to the presence of the deprotonated acidic group in RB/reline system). The modulation of fluorescence depends on the concentration of RB at the GO surface, at the reline surface, in the background DES solution, or in negatively charged ion-pair form. Among them, the above ion-pair form can be used as a model for a sustained movement of similar materials (drugs, dyes, proteins, etc.) toward their respective sites of delivery. The work may find use in sensor applications.

Chapter-6: A Polymer Blend Nanocomposites for the Separation and Purification of Gases for Different Applications

Graphene-based membranes, practical implementation in real-world applications poses concerns and challenges. Effective management of ultra-thin membranes under harsh industrial conditions for long-term usage is crucial. Therefore, continuous efforts are needed to develop novel graphene-based membranes with improved energy efficiency. Extensive research has focused on porous graphene and GO nanocomposite membranes for gas separation[20,31]. The precise preparation of single-layer GO membranes is of utmost importance. GO substrates enhance membrane thickness and penetrating flux, and provide mechanical strength for composite membrane fabrication. Graphene oxide exhibits a hexagonal pattern and contains functional oxygen groups on its surface, enabling versatile interactions with other molecules through sp^2 hybridization and π-interactions. Additionally, graphene oxide dissolves easily in water and other solvents due to the presence of oxygen functional groups. Researchers have successfully fabricated nano-porous gas separation polymer/graphene membranes.

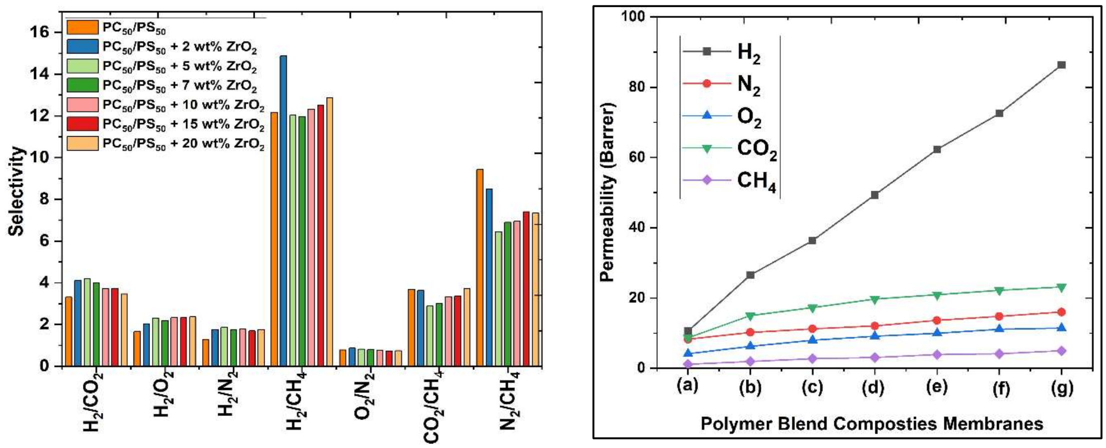


***Fig.8:* Gas permeability/selectivity of polymer blend nanocomposite**

Graphene based nanocomposites dispersed in a polymer blend Polystyrene (PS)/Polycarbonate (PC) nanocomposite membranes have been prepared by the solution cast method for gas permeation application. Study of blends of polymers that were prepared in different ratios of weight percentage and composite with different wt% of nanocomposites. The structural and morphological properties of these prepared composite membranes have been characterized using gas permeation, SEM, and EDX. UV Spectroscopy and FT-IR have measured the composite membranes' optical absorbance.

Chapter-7: Antioxidant, Antimicrobial, and Photocatalytic Activity of the Nanocomposites

This chapter explores the multifunctional properties of nanocomposites in the fields of antioxidant activity, antimicrobial activity, and photocatalysis. It delves into the application of nanocomposites in various industries, highlighting their potential in providing enhanced protection against oxidative stress, combating microbial growth, and harnessing light energy for catalytic reactions. The chapter provides an overview of the underlying mechanisms, recent advancements, and future prospects in this exciting field, showcasing the potential of nanocomposites as versatile materials with significant implications in areas such as healthcare, environmental remediation, and energy production.

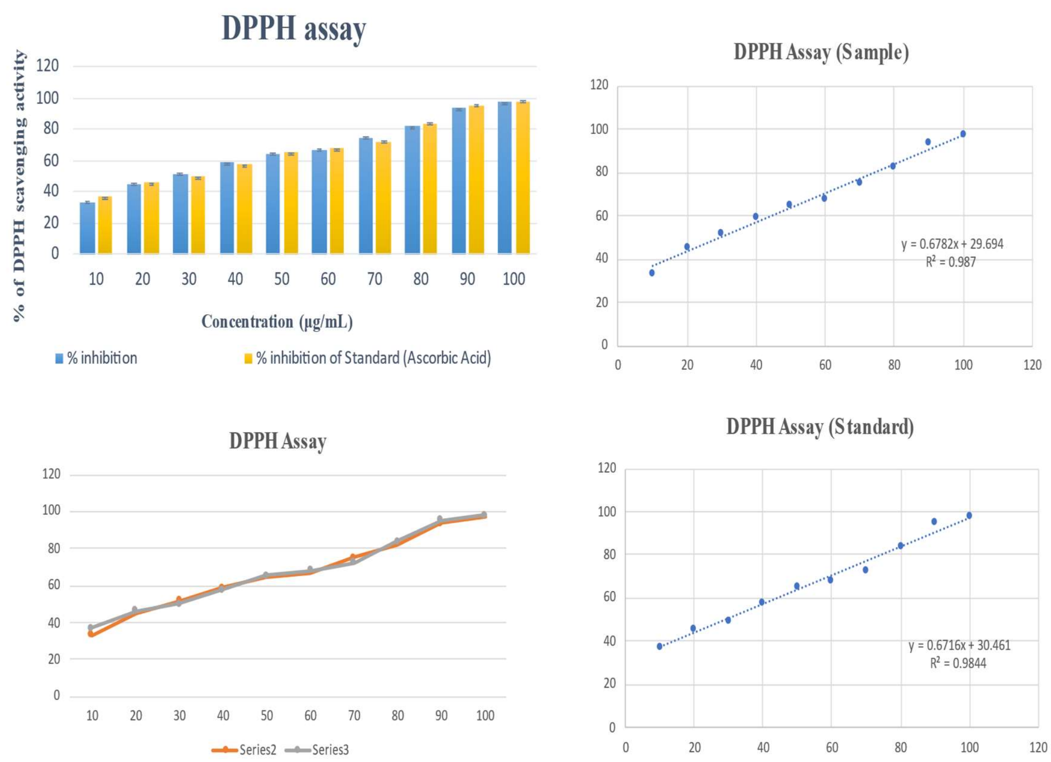


***Fig.9:* DPPH anti-oxidant inhibition activity**

The above graphs depict the DPPH anti-oxidant inhibition activity of the nanocomposite. The nanocomposite shows a similar level of antioxidant activity when it was compared to the standard ascorbic acid proving itself as an effective radical scavenger. The IC_{50} value of the same were also calculated with the standard error whose p value <0.5.

Chapter-8: Conclusions and Future Work

This chapter concludes and summarizes this thesis work's most important findings and potential applications. This chapter also includes the future research directions and scope in the field of graphene-based nanocomposites. Graphene based nanocomposites are functionalized and modified with surfactants/deep eutectic solvents. Dye adsorption on these nanocomposites has been studied. Various kinetics models and isotherm models were used for the dye adsorption study. The findings of the present study can have potential applications to develop an economic strategy for the purification of industrial dye effluent with a concomitant redressal of aquatic pollution. Photophysical modulation of dye in deep eutectic solvent with or without additives (GO/Surfactant) has been studied. The findings of the work have implications in searching potential fluorescent levels/sensors for photophysics, photobiology, or wider vehicle range for sustained drug delivery. Polymer blends (PC/PS) are prepared with graphene based nanocomposites for gas separation and permeation. These membranes are very useful in the field of fuel cells, energy storage, food packaging, etc. Graphene nanocomposites are further used for antioxidant, antimicrobial, and photocatalytic activity. A study providing enhanced protection against oxidative stress, combating microbial growth, and harnessing light energy for catalytic reactions.

Looking ahead, future work in this field could focus on several aspects. Further advancements in the synthesis techniques of nanocomposites, including graphene-based metal oxides, would be beneficial for tailoring their properties. Additionally, exploring novel functionalization methods and investigating the potential of DESs and surfactants for modification could lead to improved performance and expanded applications. Also, my research will focus on the utilization of DES in nanoparticle synthesis, exploring their potential as green and sustainable solvents for the preparation of various nanoparticles. Also investigate the effects of different DES compositions and conditions on the size, morphology, and properties of the synthesized nanoparticles. Additionally, my aim is to explore the modification of materials using DES, seeking to enhance their performance and functionality. Another area of interest will be the investigation of surfactant CMC in DES systems, studying their behavior and optimizing their use for various applications.

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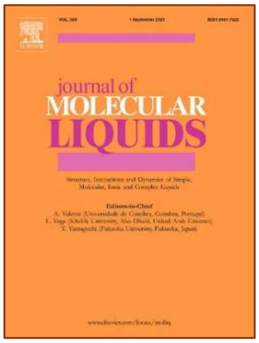
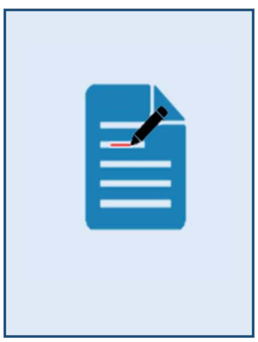
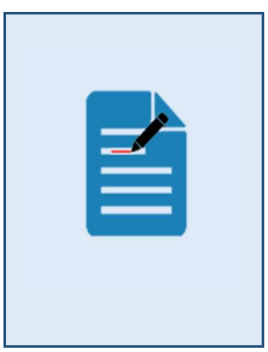
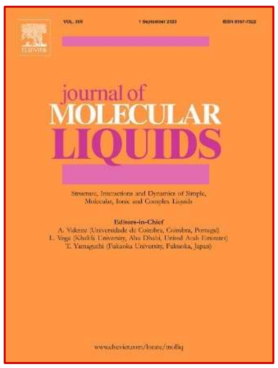
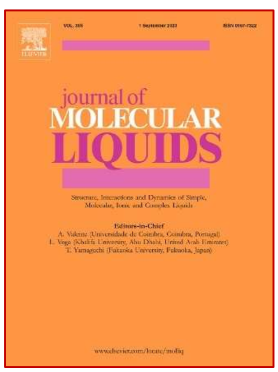
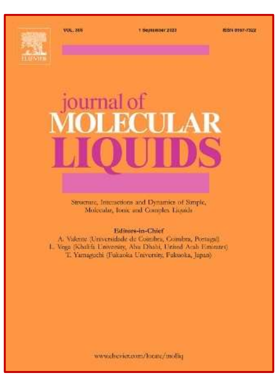
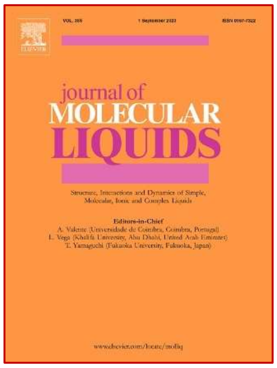
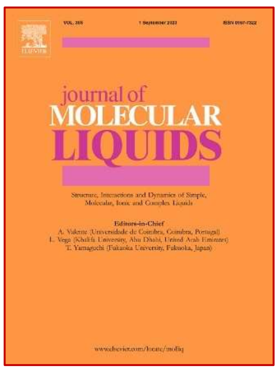
❖ List of Publications (Related to Thesis)

1.		**Title: GO/Ionic Surfactant Inspired Photophysical Modulation of Rhodamine B in Reline with or without Additives** **Vishwajit Chavda,** Darshna Hirpara, Sanjeev Kumar **Journal of Molecular Liquids**, Volume 368, p. 120614 **Available Online:** 18 October 2022 **DOI:** https://doi.org/10.1016/j.molliq.2022.120614
2.		**Title: A Sustainable Approach for the Adsorption of Methylene Blue from Aqueous Background: Adsorbent Based On DES/CGS Modified GO@ZrO$_2$** **Vishwajit Chavda,** Brijesh Patel, Sneha Singh, Darshna Hirpara, V. Devi Rajeswari, Sanjeev Kumar **RSC Sustainability,** Under review **Manuscript ID:** SU-ART-07-2023-000236
3.		**Title: Separation and purification of the Hydrogen gas for the fuel cell application: A polymer blend composites of PC/PS-DES-GO/ZrO$_2$** **(Manuscript under preparation)**
4.		**Title: GO/Surfactant Inspired Photophysical Modulation of Congo Red in Deep Eutectic Solvents with or without Additives** **(Manuscript under preparation)**

5.		**Title: Antioxidant, Antimicrobial, and Photocatalytic Activity of the Nanocomposites: A case of Deep Eutectic Solvent modified GO@ZrO_2** **(Manuscript under preparation)**

❖ List of Publications (Non-related to Thesis)

1.		**Title: Micellization of conventional and gemini surfactants in aquoline: A case of exclusively water based deep eutectic solvent** Darshna Hirpara, Brijesh Patel, **Vishwajit Chavda**, Sanjeev Kumar **Journal of Molecular Liquids**, Volume 362, p. 119672 **Available Online:** 24 June 2022 **DOI:** https://doi.org/10.1016/j.molliq.2022.119672
2.		**Title: Micellization and clouding behaviour of an ionic surfactant in a deep eutectic solvent: A case of the reline-water mixture** Darshna Hirpara, Brijesh Patel, **Vishwajit Chavda**, Arpita Desai, Sanjeev Kumar **Journal of Molecular Liquids**, Volume 364, p. 119991 **Available Online:** 2 August 2022 **DOI:** https://doi.org/10.1016/j.molliq.2022.119991
3.		**Title: Micro-Environment mapping of mole fraction inspired contrasting charged aqueous gemini micelles: A drug solubilization/release study** Brijesh Patel, Sneha Singh, Kushan Parikh, **Vishwajit Chavda**, Debes Ray, Vinod K. Aswal, Sanjeev Kumar **Journal of Molecular Liquids**, Volume 363, p. 119885 **Available Online:** 18 July 2022 **DOI:** https://doi.org/10.1016/j.molliq.2022.119885

4.		**Title: Composition triggered Aggregation/Solubilization behaviour of mixed counter charged Gemini Surfactants: A Multi-technique investigations** Brijesh Patel, Sneha Singh, Kushan Parikh, **Vishwajit Chavda**, Darshna Hirpara, Debes Ray, Vinod K. Aswal, Sanjeev Kumar **Journal of Molecular Liquids**, Volume 359, p. 119242 **Available Online:** 28 April 2022 **DOI:** https://doi.org/10.1016/j.molliq.2022.119242
5.		**Review** **Title: Exploring the potential of deep eutectic solvents in pharmaceuticals: Challenges and opportunities** Priyanka A. Shah, **Vishwajit Chavda**, Darshna Hirpara, Vinay S. Sharma, Pranav S. Shrivastav, Sanjeev Kumar **Journal of Molecular Liquids,** Under review **Manuscript ID:** MOLLIQ-D-23-04707

❖ Work presented in Conferences/ Seminars/ Workshops

Conferences		
1.		Title: **Synthesis and Characterization of Graphene Oxide and Their composites with Metal Oxide** **Vishwajit Chavda,** Sanjeev Kumar **National Conference** on *Recent Advances and Future Trends in Biological, Chemical and Physical Science 2021 (RAFTBCPS-2021)*, **30^{th} -31^{st} July 2021**. **Presented Session:** **POSTER** Received "1^{st} Price for Best Poster" Award
2.		Title: **Synthesis and Characterization of GO@ZrO_2 Nanocomposite** **Vishwajit Chavda,** Sanjeev Kumar 4^{th} **National Conference** *in Chemistry 2021,* **6^{th} -7^{th} August 2021**. **Presented Session:** **ORAL** Received "One of the Best Talks" Award
3.		Title: **Synthesis of Graphene oxide using Deep Eutectic Solvent: A Greener Approach** **Vishwajit Chavda,** Sanjeev Kumar **International Conference** on *Complex Fluids and Soft Matter 2021 (Compflu-2021),* **13^{th} -15^{th} December 2021**. **Presented Session:** **ORAL**
4.		Title: **Deep eutectic solvent effect on fluorescence of ionic dyes with or without graphene oxide** **Vishwajit Chavda,** Sanjeev Kumar **International Conference** on *Advanced Materials and Applications (ISAMA-2022),* **18^{th} July 2022.** **Presented Session:** **POSTER**

5.		Title: **Fabrication of Reline Assisted ZrO_2/GO Nanocomposite (REL-GO@ZrO_2) for Efficient Removal of Methylene Blue** **Vishwajit Chavda,** Sanjeev Kumar *9th* **Interdisciplinary Symposium** *on Materials Chemistry (ISMC-2022),* **7th-10th December 2022.** **Presented Session:** **POSTER**
6.		Title: **GO Driven Fluorescence Modulation of Rhodamine B in Aquoline: A Water-Based Deep Eutectic Solvent** **Vishwajit Chavda,** Sanjeev Kumar *30th CRSI-NSC & 16th CRSI-RSC* **Symposium Series** *in Chemistry,* **2nd-6th February 2023.** **Presented Session:** **POSTER**
7.		**PARTICIPATED** **Vishwajit Chavda,** Sanjeev Kumar **International Conference** *on Vital Role of Polymers in Drug Delivery,* **13th -14th August 2021**.
8.		**PARTICIPATED** **Vishwajit Chavda,** Sanjeev Kumar **International Conference** *on Surface Chemistry: Colloids and Interface Aspects with Applications (SCCIA-2022),* **3rd-7th January 2022.**
9.		**PARTICIPATED** **Vishwajit Chavda,** Sanjeev Kumar **International Conference** *on 9th Asian Network for Natural & Unnatural Materials (ANNUM-9),* **8th April 2022.**

Workshops		
10.		**Vishwajit Chavda** **7-Day Training program** *Synergistic Training program Utilizing the Scientific and Technological Infrastructure* ***(STUTI)*** on Advances in Characterization of Materials,**12th-18th September 2022**.
11.		**Vishwajit Chavda** **7-Day Training program** *Synergistic Training program Utilizing the Scientific and Technological Infrastructure* ***(STUTI)*** on Modern Spectroscopic, Thermal and Microscopic Techniques, **21st -27th September 2022.**
12.		**Vishwajit Chavda** **One-Day workshop** Early Career Researchers by Inspiring India in Research, Innovation, and STEM Education (iRISE*) on* *IP and Knowledge Management*, **28th September 2022.**
13.		**Vishwajit Chavda** **7-Day Training program** *Synergistic Training program Utilizing the Scientific and Technological Infrastructure* ***(STUTI)*** on Advanced Characterization Techniques in Condensed Matter, **17th -23rd January 2023.**
14.		**Vishwajit Chavda** **One-Day Training Program** *Developing Skills* on Advancing Knowledge from Quantum mechanical Perspectives in materials science, **15th April 2023.**

Webinars		
15.	ROYAL SOCIETY OF CHEMISTRY	**Vishwajit Chavda** **Online Webinar** *ChemSci2021- Leaders in the Field of Symposium,* **14th December 2021.**
16.	ACS Chemistry for Life®	**Vishwajit Chavda** **Online Webinar** *ACS publications symposium innovation in measurement science,* **20th October 2022.**
17.	ACS Chemistry for Life®	**Vishwajit Chavda** **Online Webinar** *Trends in Physical Chemistry,* **9th June 2023.**

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(Research Scholar)

Dr. Sanjeev Kumar
(Guide)