Indian Science Technology and Engineering Facilities Map (I-STEM)

1. Partial financial support for using R&D facilities in other institutions through the I-STEMweb portal to Users from Academic Institutions and Start-ups (Format-1)

(i) Personal info

(a) Nesleena P. (Ph.D. Guide: Dr. Mini Mol Menamparambath)
(b) National Institute of Technology Calicut
(c) Department of Chemistry
(d) Ph.D. in Chemistry

(ii) Project Topic

a) Title:

Synthesis of two dimensional nanomaterials for the fabrication of sensors and energydevices

b) Sub area:

Conducting Polymers (CPs) and Transition Metal Composites (TMCs)

c) Area description:

Two dimensional (2D) nanomaterials comprise a wide range of promising materials that can be modified in enormous ways to obtain materials and devices with real-time applications. The proposed project mainly focuses on developing facile and novel synthetic routes for 2Dconducting polymers (CPs) and Transition Metal Composites (TMCs) over conventional methods. Interface-assisted in-situ synthesis is a powerful emerging tool contrary to other bulk or single-phase polymerization techniques. Interfaces adopted in chemical reactions include air-liquid, air-solid, liquid-liquid, and liquid-solid interfaces. Furthermore, the liquid-liquid interface-assisted synthesis predominates in the fabrication of CPs and TMCs.Herein, we primarily target to explore the remarkable ability of the liquid−liquid interface of two immiscible solvents to tune the morphology to obtain nanomaterials with desired properties.

d) Aims and Objectives

- Insitu synthesis of 2D nanomaterials via liquid- liquid interface assisted technique:
  - Synthesis and optimization of the physico-chemical properties of binary TMCs
  - Insitu synthesis of CPs and their nanomaterial hybrids using various polymers.

- Investigation on the morphology and growth patterns of CPs at various interfaces to overcome limitations in their pristine form.
- Fabrication of electrochemical sensors for the detection of biomolecules, particularly neurotransmitters.
- Development of self-powered, cost-effective, and self-healable next-generation energy devices and techniques that are highly important in strengthening small-scale electronic devices.

e) Duration : 6 months

f) Project Summary

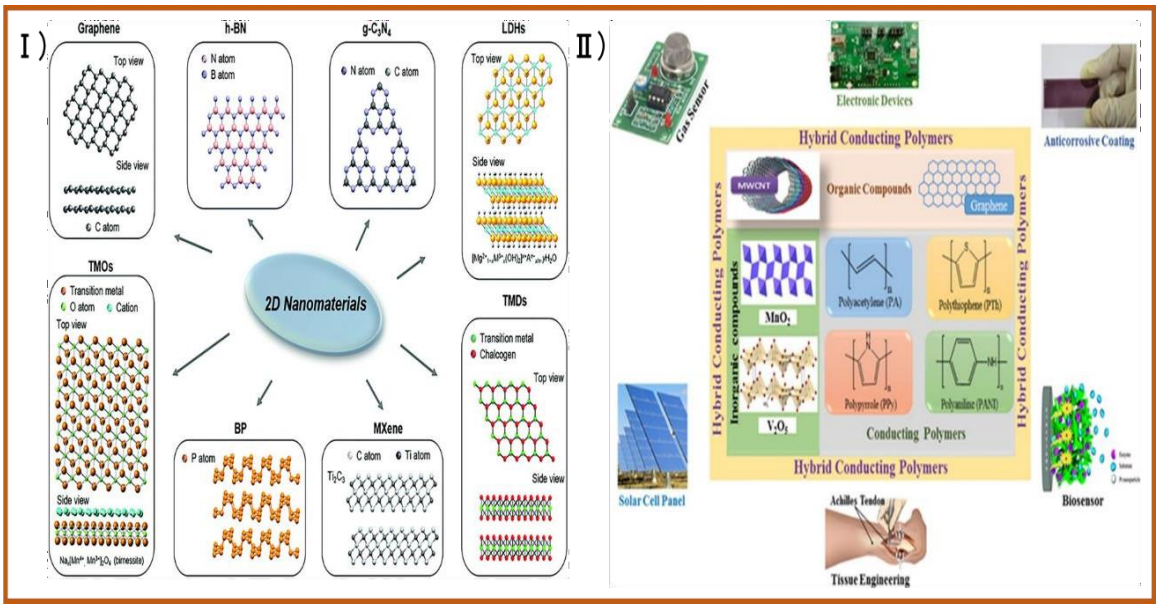


Figure 1. (I) *Schematic representation of various 2D nanomaterials.*[3] **(II)***Various conducting polymers and their applications.*[1]

The ingenious scientific quest and dedicated efforts toward soft and flexible electronics triggered a meteoric rise in two dimensional nanomaterials that possess intriguing physico-chemical properties due to their uniform shapes, low cost, high surface-to-volume ratios, and surface charge. The past decade witnessed a plethora of diverse 2D materials with a wide range of applications in various scientific fields, including functional electronics, catalysis, supercapacitors, batteries, and energy materials. They also have significant contributions in the biomedical field, especially nanomedicine, drug-gene delivery systems, multimodal imaging, biosensing, antimicrobial agents, and tissue engineering.[1] Recently, 2D nanomaterials such as graphene, graphene oxide (GO), reduced graphene oxide (rGO), layered double hydroxides (LDHs), transition metal dichalcogenides (TMDs), transition metal

oxides (TMOs), and conducting polymers (CPs) find application in the development of several (bio)electronic and energy devices in the form of electrodes, biosensors, electronic skin, wearable electronics, human motion sensors, health monitoring, or soft robotics **(Figure 1).**[2]

Among the various techniques employed for the synthesis of 2D materials, their controlled assembly at different interfaces (liquid-solid, gas-liquid, liquid-liquid, and gas-solid) offer unique reaction dynamics in tuning the properties of these nanostructures **[Figure 2 (I)].** The interface is acclaimed to afford a unique non-equilibrium environment with enhanced surface energy for the assembly of precursors to initiate the nucleation, leading to further growth of the intermediates to form the final structure with desired morphology.[4] L-S interfacial polymerization method allows monomers dispersed in a liquid phase to react with the solid surface. The concrete surface can be a 2-D template such as ice surface, precursor salts, and other hard removable templates, which can simultaneously act as a template or precursor that promotes nanostructure growth through asymmetric interactions. The G-L interface system comprises a monomer/oxidant solution that polymerizes in a 2-D confined space offered by air or vacuum in close proximity to the solution phase. 2-D PEDOT:PSS sheets are synthesized on the ice surface through the chemical oxidative polymerization (COP) of EDOT monomers at the air-water interface.[5] In the L-L interface system, the monomers/oxidants are dissolved in respective immiscible solvents, leading to the formation of a visible 2-D interface and the interfacial tension controls the polymerization rate.[6] Our research group has synthesized Polypyrrole Silver (PPy/Ag) hybrid sheets through facile water–chloroform interface-assisted polymerization.[7] The pyrrole oligomers dispersed in chloroform solvent migrates towards the interface where they meet the oxidant silver nitrate dissolved in water resulting in the formation of PPy/Ag hybrid sheets. The Ag NPs were uniformly attached to the oligomer chains and indicated the role of oxidant and the interfacial tension in controlling the end polymer morphology as shown in **Figure [2(II), (III)].**[7] The 2D vapor phase polymerization (VPP) can be performed not only in the G-L liquid system, but also at the G-S interface. Here, the monomer vapors are forced to undergo COP at the G-S interface offered by the solid oxidant crystals. The oxidant crystals act as both reaction template and precursor material for the synthesis of CP and its hybrid nanostructures. Nanosheets of PPy, PEDOT and PANI were successfully prepared by VPP at the surface of $CuCl_2.H_2O$, which acts as an oxidant and template.[8] In addition to the aforementioned wide range of conducting polymers, interface-assisted synthesis has emerged as a versatile approach for the controlled and scalable synthesis of 2D Transition Metal Composites (TMCs) over conventional techniques. Interface

regulates the structure, morphology, stoichiometry, size, and crystallinity of TMCs without the requirement of removing the template post-reaction.[9]

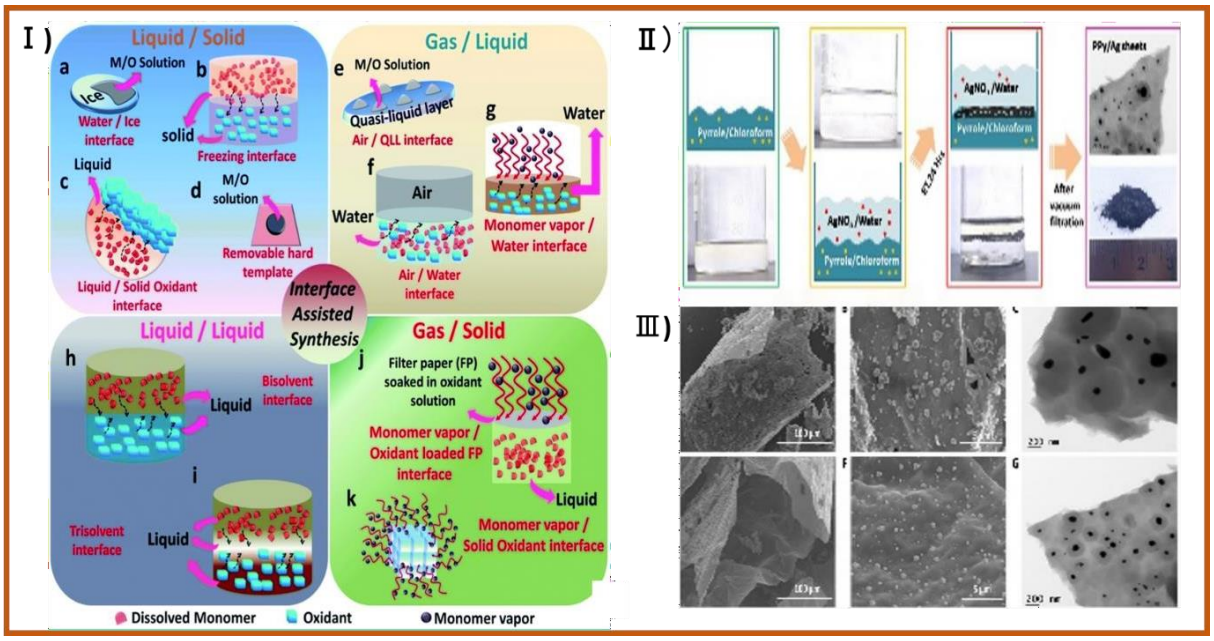


Figure 2 ***(I)*** *Schematic illustration of CP synthesis assisted by four types of interfaces: liquid-solid interface (a–d), gas-liquid (e–g), liquid-liquid (h and i) and gas-solid (j and k).* [6] ***(II)****Schematic illustration of the formation of PPy-Ag sheets by the polymerization of PPy at the water−chloroform interface.****(III)*** *SEM and TEM images of PPy-Ag showing the distribution of Ag nanoparticles in PPy sheets.*[7]

Our group has successfully developed an L-L interface-assisted synthesis mechanism toprepare one of the most important mixed TMCs, nickel cobaltite. n-butanol/water interface was employed to synthesize flake-like nickel cobaltite that can electrochemically monitor the neurotransmitter dopamine with excellent selectivity and sensitivity **(Figure 3).**[10] Furthermore, metal oxide and carbon nanotubes (CNT) interactions are deep-seated to activate high energy storage ability in energy devices and potential applications. Hence, we currently focus on $NiCo_2O_4$/MWCNT composites as a hybrid electrode in supercapacitors that delivers a specific capacitance that is more than two and half times higher than pristine $NiCo_2O_4$.[11] Owing to their increased capacitance TMCs of manganese and nickel are now being explored for the fabrication of Li batteries and solar cells.[12] The use of TMCs as sensors in biomedical field has also gained significant attention and have been used for the trace detection of various biomolecules, pathogens, and toxic compounds inside the human body.[2]

Conducting Polymer based flexible thermoelectric generators (TEGs) are an emerging class of state-of-the-art materials due to their intrinsic flexibility, low cost, and none or low toxicity. The research on flexible TEGs are still at a very preliminary stage, and more fundamental

studies are needed to explore the strategies for improving the performance of flexible and self healable TE devices, such as understanding the delocalizing carriers in conductive polymers, theoretically establishing models that explain carrier transport properties, optimizing theeffects of fillers through interfacial engineering, intensifying the connections between inorganic particles for highly crystalline films, and overcoming the mechanical inflexibility ofinorganic TE materials as legs.[13]

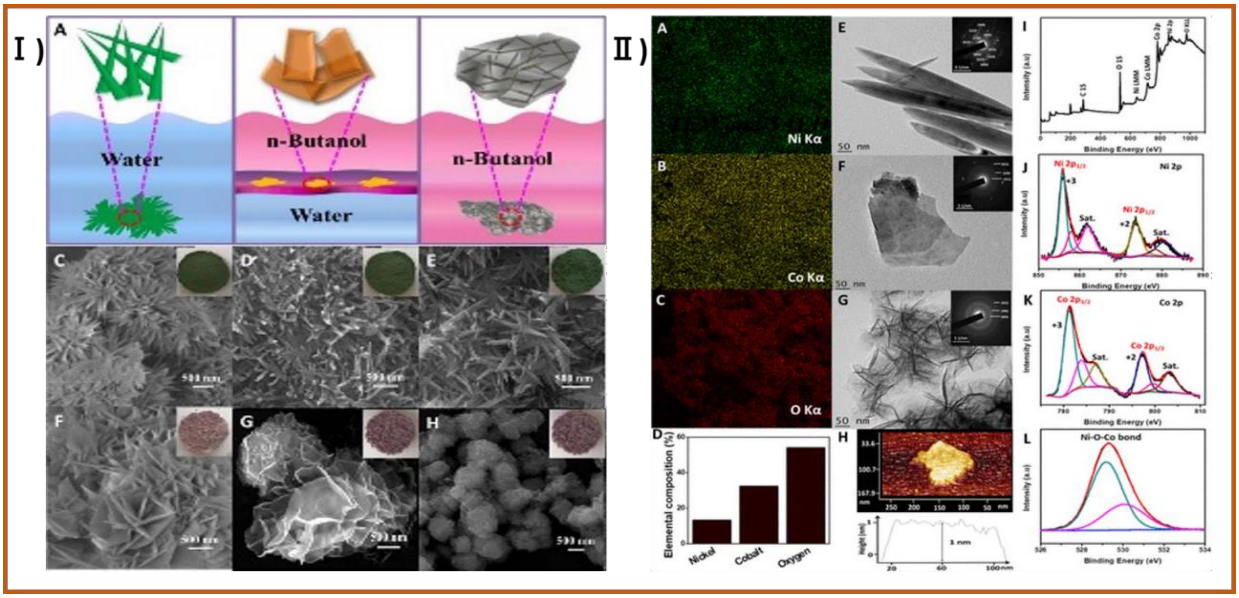


Figure 3. ***(I)*** *A.Schematic representation of the morphology tuning of the nickel cobaltite in the water system, n-butanol/water bisolvent system, and butanol system. SEM images of the produts obtained in aqueous phase (C), butanol- water phase at different solvent ratios (D)-(G) and organic phase (H).* ***(II)*** *Elemental mapping images and the graphical representation of the atomic percentages of nickel, cobalt, and oxygen present. HRTEM and the corresponding SAED patterns, Atomic force microscopy image with corresponding thickness profiling and XPS spectra survey scan with deconvoluted spectra of nickel (J), cobalt (K), and oxygen (L).*

We have a group exclusively focusing on PEDOT-based thermoelectric materials in which various dopants are introduced through in-situ polymerization to enhance intrinsic conductivity. The additive manufacturing of CPs that include combination with other polymers and nano additives presents excellent opportunities to design new (bio)electronic devices. In this regard, the 3D printing of CPs explored very recently portrays a field with many possibilities and applications in the future. Among the CPs used for 3D printing, PEDOT is the most studied. PEDOT-based inks have been processed employing several 3D printing techniques: inkjet, extrusion, electrohydrodynamic, and light-based printing. But not only that, PEDOT:PSS has also been processed in combination with other polymers, solvents, hydrogels, and conducting fillers leading to tailor-made inks with tunable conducting properties.[16] Similarly, it is worth mentioning that other 2D materials, that is, MXenes, metal−organic frameworks (MOFs), and graphenes, among other emerging 2D nanomaterials, represent a big

challenge to be mixed with CPs and processed by 3D printing to form hybrid conducting materials with several possibilities and new applications. **Figure (4)** represents 3D printing of conducting polymer ink as a promising route for facile and streamlined fabrication of high resolution and multi-material conducting polymer structures and devices.[15]

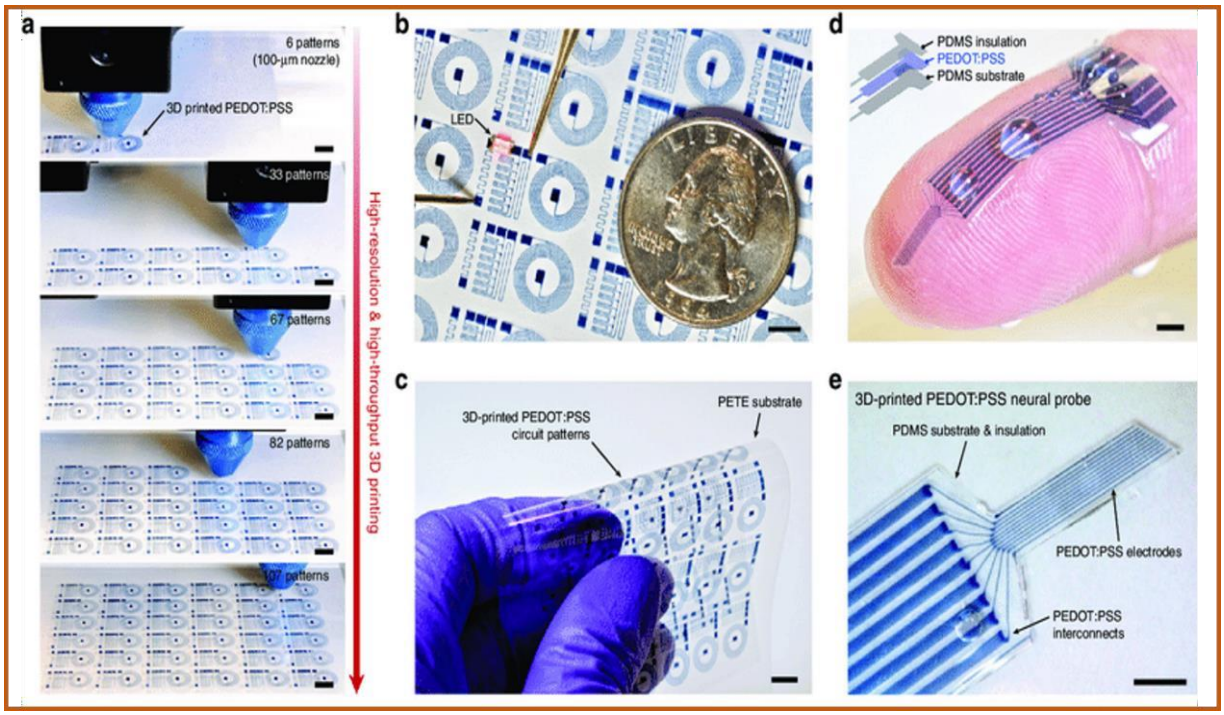


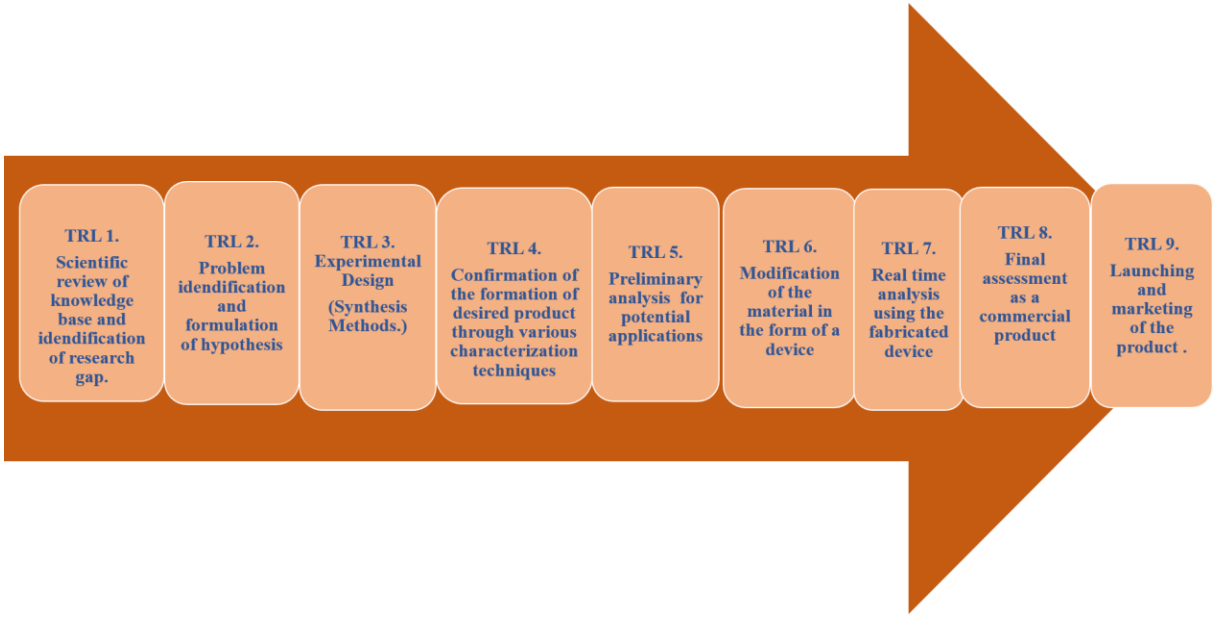
Figure 4. *3D printing of conducting polymer devices.* ***a)*** *Sequential snapshots for 3D printing of high-density flexible electronic circuit patterns by the conducting polymer ink.* ***b)*** *Lighting up of LED on the 3D-printed conducting polymer circuit. PETE indicates polyethylene terephthalate.* ***c)*** *Bending of the 3Dprinted conducting polymer circuit without failure.* ***d)*** *Image of the 3D-printed soft neural probe with 9-channels by the conducting polymer ink and the PDMS ink.* ***e)*** *Image of the 3D-printed soft neural probe in magnified view.*[15]

Highly reproducible 3D printing of conducting polymers in high resolution allows the rapid fabrication of large number of circuits on flexible substrates such as polyethylene terephthalate (PETE) by a single continuous printing process. The resultant 3D-printed conducting polymer electronic circuits exhibit high electrical conductivity to operate electrical components such as a light emitting diode (LED) and flexibility to withstand bending without mechanical failure. 3D printed flexible PEDOT:PSS microstructures that can be employed as soft neural probes for in vivo single-unit recording.[1] Electrophysiological recording performed by coupling the 3D-printed soft neural probe with Neuro Nano Strip Connectors showed that the 3D-printed soft neural probe could record continuous neural activities in a freely moving mouse over two weeks. In addition to this, there are emerging printing methodologies, such as selective laser sintering, two-photon polymerization printing (2PP), volumetric printing, and fused filament fabrication, that remains mostly unexplored for conducting polymers, opening a new door of possibilities and applications in the future.[14] Hence, the project aims to explore these emerging

printing methods for the fabrication of CPs and TMCs based electronic devices for multifunctional applications.

g) Technical details

a) TRL



b) Methodology

Synthesis of diverse 2D nanomaterials using interface assisted technique

The morphology, size, and physico-chemical properties of 2D nanomaterials make them an inherent material for the synthesis of new-generation material. Among the several strategies adopted for the synthesis of 2D nanomaterials, we focus on liquid-liquid interface aided technique, a versatile emerging approach for the controlled synthesis of various nanostructures. Owing to the simplicity in the synthesis technique and cost-effectiveness, this method can be considered as an efficient route to the synthesis of different CPs and TMOs with desired properties. A schematic diagram of the single phase and liquid-liquid interface assisted synthesis technique is given in **Figure (5).**[5]

The choice of immiscible solvents and their ratio results in the formation of nanostructures with diverse morphology. The molecular arrangement and crystal nucleation control are greatly affected by the surface energy at the liquid-liquid interface. The hydrogen-bonding guided dissymmetric interactions of the reacting species and the polarity of the interface render exceptional properties to the materials formed at the interface compared to the bulk reaction.[6] This method can thus be employed to synthesize dopants-based CPs and TMOs. In addition to chemical doping, the oxidation level of conducting polymers can be easily tuned by

electrochemical doping/dedoping processes. This fine-tuning of the electronic properties of a polymer allows theoretical studies to be carried out to obtain a better understanding of the doping effects from a molecular level, which can guide the future development of organic thermoelectric (OTE) materials.

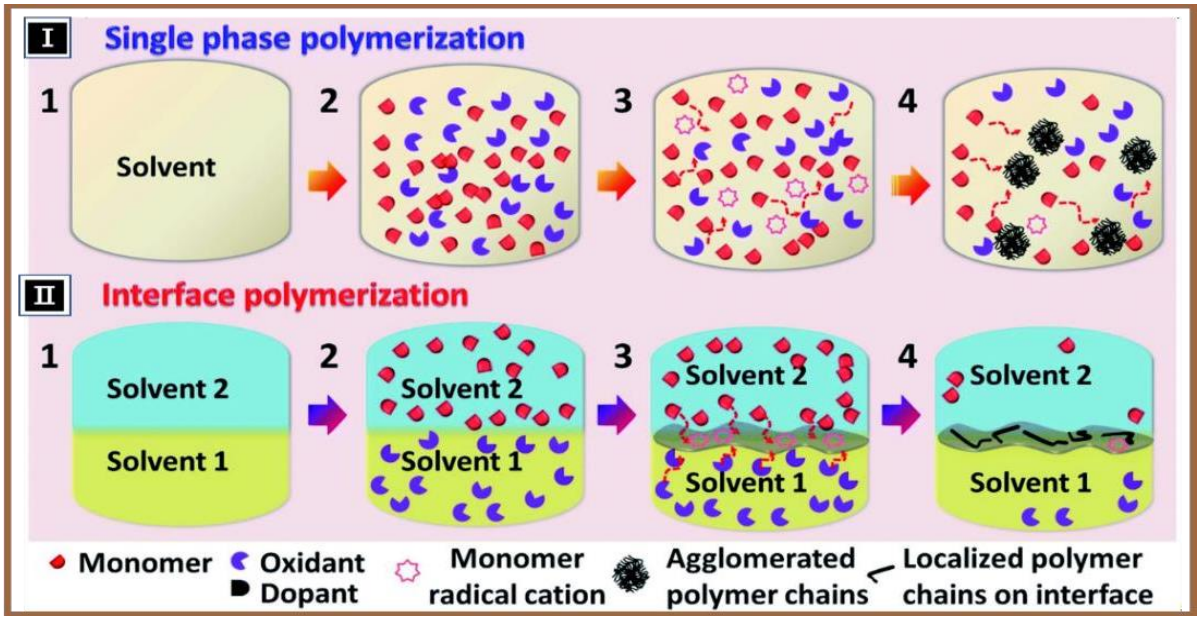


Figure 5. *Schematic illustration of **(I)** single phase and **(II)** interface polymerization mechanisms, in which 1 to 4 represent the various steps of each polymerization mechanism. (1) a suitable solvent is taken in a reaction vessel, (2) monomer and oxidant molecules are dispersed in the solvent, (3) the initiation of the polymerization reaction, and (4) the subsequent polymerization steps followed by secondary growth of oligomer chains attributed to the formation of agglomerated nanostructures. **(II)**Interface polymerization starts with the following: (1) two immiscible solvents were taken in a reaction vessel, (2) monomer and oxidant molecules were dispersed in the corresponding solvents, (3) formation of a distinguishable interface between two immiscible solvents, followed by the formation of monomer radical cations delocalized at the interface through the redox reaction between monomer and oxidant molecules and (4) localization of polymer chains at the interface due to the high interfacial tension.*[5]

Charge carrier ability of these nanostructures, dominated by interchain coupling, largely depends on morphology. Also, chemical defects, including twisted and kinked chains, are responsible for decreasing intrachain charge carrier mobility. Hence, higher purity and crystallinity are required to improve the performance of these materials. A detailed study on the reaction dynamics at the interface can render information regarding the nature of microemulsions where the precursors interact and subsequently result in the formation of nanostructures. A more systematic computational study can reveal the exact reaction mechanism and the growth pattern of the these. A DFT study can further provide a clear picture on the effect of doping in these 2D materials and the dominant defects.

c) Design and development

Fabrication of wearable and stretchable devices

The proposed project mainly targets multiple critical areas of research that include device fabrication for energy conversion and storage, for the detection of neurotransmitters, various drugs, and explosives. **Figure 6 (Ia)** shows a nicotine s-band consisting of a flexible electrode array connected to a compact printed circuit board. During on-body use, the s-band is worn on the subject's forearm to detect the level of nicotine in human sweat after nicotine inhalation. The cross-sectional layers of the electrode array are shown in **Figure 6 (Ib).** On a poly(ethylene terephthalate) (PET) film, a gold working electrode is grown with gold nanodendrites and modified with cytochrome P450 2B6 (CYP2B6), a nicotine-oxidizing enzyme. A silver/silver chloride reference electrode and a gold counter electrode are also integrated. **Figure 6 (Ic)** the functionalized working electrode. Gold nanodendrites are directly grown on the gold electrode, and a self-assembled monolayer of 11-mercaptoundecanoic acid (MUA) is coated on top.[16]

Hybrid organic- inorganic polymer composites present a unique way to optimize the performance of thermoelectric devices through proper molecular and interfacial designs. The use of an insulating polymer as a matrix is also a possible solution to improve the stability of the TE properties of organic semiconductors under mechanical stress. **Figure 6 (II)** shows self-healing and stretchable PEDOT:PSS based composites with the addition of various polymeric surfactants. The presence of Triton X -100 creates a viscoelastic composite in which the PEDOT:PSS is dispersed in the surfactant matrix, which acts like a viscous fluid and thus, after a cut, it can freely flow from both sides of the separated regions and form a physical contact, effectively ending the "wound" thus allowing the composite to recover its thermoelectric and electrical properties. On the other hand, the use of the ionic liquids (IL) allowed increasing at the same time both S and σ of PEDOT:PSS, by modifying the doping level and nanostructure of PEDOT:PSS via an ion-exchange process. In addition, the presence of the IL resulted in the formation of PEDOT:PSS nanofibrils embedded in a soft matrix, improving its mechanical stretchability.[16] In the proposed project,we mainly focus on similar wearable devices as real time monitors using doped CPs and TMCs.

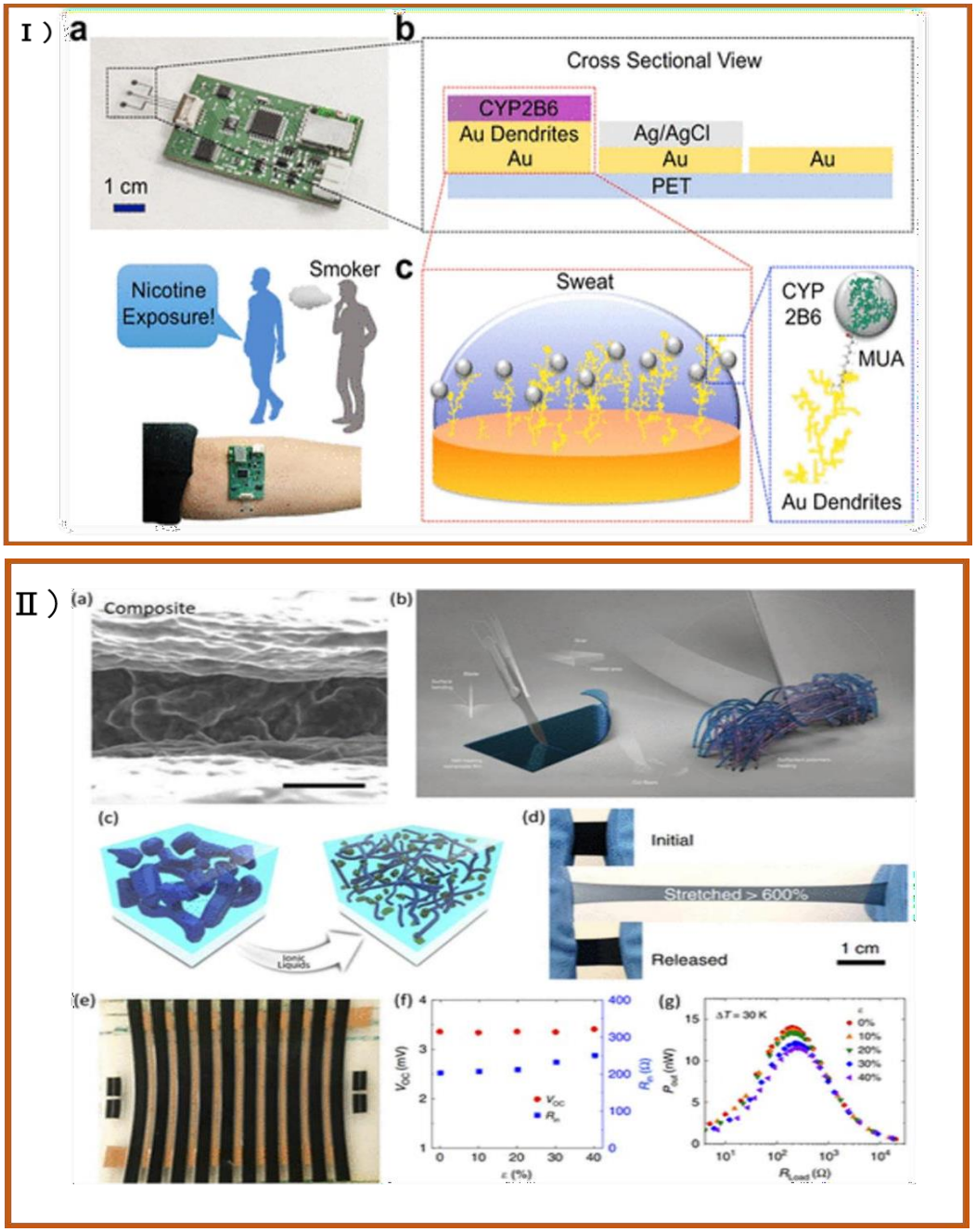


Figure 6 (I). *Design and application of the s-band. (a) Optical image of a nicotine s-band and a schematic showing the application of the wearable device on monitoring secondhand smoke. (b) A cross-sectional illustration of the flexible sensor patch, which consists of a functionalized working electrode modified with the CYP2B6 enzyme, a reference electrode pasted with silver/silver chloride, and a counter electrode. (c) Zoom-in schematics of the functionalized working electrode, which has gold nanodendrites grown on top of the gold substrate. The nanodendrites are connected to CYP2B6, a nicotine-oxidizing enzyme, via a self-assembled monolayer of 11-mercaptoundecanoic acid (MUA).*[14] ***(II)*** *SEM image of the cut on the PEDOT:PSS/Triton X-100 composite film and (b) Schematic illustration for the mechanicaland thermoelectrical self-healing process of the composite film. (a−b) (c) Schematic of the IL-induced morphological transition of PEDOT:PSS from the amorphous structure into crystalline nanofibrils inserted in IL-assisted soft domains*. (d) Schematic of the stretchability of the PEDOT:PSS polyurethane-IL composite. *(e) Photograph of a stretchable TE module composed of 10 legs. (f) VOCs and Rin vs tensile strain (ε) applied to a module at ΔT = 30 K. (g) Pout vs load under different strains at ΔT = 30 K.* [16]

d) Facilities and instrumentation required

In the area of material characterization, basic instrumentation facilities such as Fourier transform infrared spectroscopy (FTIR) and ultraviolet–visible spectroscopy (UV-Vis) are available at National Institute of Technology Calicut (NITC). Other necessary characterizations include X-ray powder diffraction (XRD), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), Small Angle X-ray Scattering (SAXS), Wide Angle X-ray Scattering (WAXS), FT-Raman Spectroscopy, Gas Chromatography Mass Spectrometry (GCMS), Scanning Electron Microscope (SEM) and High-resolution transmission electron microscopy (HR-TEM) equipped with a high energy resolution x-ray EDS analyser and elemental mapping, atomic force microscopy (AFM) and Xray photoelectron spectroscopy (XPS), to obtain elemental composition at a submicron scale, will have to be performed in other institutes. The electrochemical studies can be conducted using the electrochemical workstation which is available in the laboratory and the conductivity of the prepared samples can be measured using standard four probe method, which is available in the institute. The team need to utilize all of the above facilities for proper understanding of physical and chemical properties of the synthesised nanomaterials to be eventually modified for various applications.

e) Consumables

Not applicable

References

1. Namsheer, K. & Rout, C. S. Conducting polymers: a comprehensive review on recent advances in synthesis, properties and applications. *RSC Adv.* **11**, 5659–5697 (2021).
2. Hu, T. *et al.* Two-dimensional nanomaterials : fascinating materials in biomedical field. *Sci. Bull.* (2019) doi:10.1016/j.scib.2019.09.021.
3. Zeng, M. *et al*. Engineered two-dimensional nanomaterials: An emerging paradigm for water purification and monitoring. *Mater. Horizons* **8**, 758–802 (2021).
4. Poolakkandy, R. R. & Menamparambath, M. M. Soft-template-assisted synthesis: A promising approach for the fabrication of transition metal oxides. *Nanoscale Adv.* **2**, 5015–5045 (2020).
5. Barpuzary, D., Kim, K. & Park, M. J. Two-Dimensional Growth of Large-Area Conjugated Polymers on Ice Surfaces: High Conductivity and Photoelectrochemical Applications. *ACS Nano* **13**, 3953–3963 (2019).
6. Chondath, S. K. & Menamparambath, M. M. Interface-assisted synthesis: a gateway to effective nanostructure tuning of conducting polymers. *Nanoscale Adv.* **3**, 918–941 (2021).
7. Chondath, S. K. *et al*. Water-Chloroform Interface Assisted Microstructure Tuning of Polypyrrole-Silver Sheets. *ACS Appl. Mater. Interfaces* **11**, 1723–1731 (2019).
8. Huang, L. *et al.* Large-scale synthesis of size- A nd thickness-tunable conducting polymer nanosheets: Via a saltlated method. *J. Mater. Chem. A* **7**, 24929–24936 (2019).
9. Poolakkandy, R. R. & Menamparambath, M. M. Transition metal oxide based non-enzymatic electrochemical sensors: An arising approach for the meticulous detection of neurotransmitter biomarkers. *Electrochem. Sci. Adv.* **1**, 1–24 (2021).

10. Rahman Poolakkandy, R., Kaladi Chondath, S., Puthiyottil, N., Davis, D. & Menamparambath, M. M. N-Butanol/Water Interface-Aided Physicochemical Tuning of Two-Dimensional Transition-Metal Oxides. *Langmuir* **36**, 872–879 (2020).

11. Shobha, Bhaskaran, Singh, M., Negi, C. M. S. & Gupta, S. K. Improved electrochemical performance of nickel cobaltite/ multi-walled carbon nanotube composite as a hybrid electrode for supercapacitors. *J. Phys. Chem. Solids* **154**, 110107 (2021).

12. Qi, W. *et al.* Nanostructured anode materials for lithium-ion batteries: Principle, recent progress and future perspectives. *J. Mater. Chem. A* **5**, 19521–19540 (2017).

13. Xu, S. *et al.* Conducting polymer-based flexible thermoelectric materials and devices: From mechanisms to applications. *Prog. Mater. Sci.* **121**, 100840 (2021).

14. Criado-Gonzalez, M., Dominguez-Alfaro, A., Lopez-Larrea, N., Alegret, N. & Mecerreyes, D. Additive Manufacturing of Conducting Polymers: Recent Advances, Challenges, and Opportunities. *ACS Appl. Polym. Mater.* **3**, 2865–2883 (2021).

15. Yuk, H. *et al.* 3D printing of conducting polymers. *Nat. Commun.* **11**, 4–11 (2020).

16. Tai, L. C. *et al.* Nicotine Monitoring with a Wearable Sweat Band. *ACS Sensors* **5**, 1831–1837 (2020).

h) Expected Outcome

The research project outlined here will aid in the deep understanding of the (1) liquid-liquid interface assisted synthesis strategy for the synthesis of various 2D nanomaterials ssuch as CPs and TMOs, (2) comprehensive analysis of their structural and property enhancement with various dopants (3) fabrication of wearable sensors and energy devices for real time applications (4) the mechanistic and computational studies of the growth pattern of the synthesised materials and their interaction with the analytes.

The results will be published in international journals and also presented at national/international conferences. Additionally, possible collaborations between national/international research laboratories will be established during the project. The results with commercial potential could be patented. This research program will be helpful for human resource development, in terms of training students working for their doctoral degree, research staffs intending to take up career in research and development. In addition to that this project will also be utilized to train UG/PG students as a part of their curriculum at National Institute of Technology Calicut. Moreover, this project may lead to the development of a critical set of electronic components and partner with industry to develop prototypes and commercialize the technology.

i) Industry and Institute Collaborations

Not Applicable

j) Funding required from I-STEM

Details of Requirements & Mode of the Engagement

i) Short term Engagement:

a. Usage of testing/characterization facilities across the country (Characterization Mode)

- **i)** Testing Charges (Attached separately) : Rs 2,00,000/- (Characterizations including SEM EDS MAPPING, TEM EDS MAPPING, XPS, FT RAMAN, SAXS, GIWAXS,AFM, GC-MS)
- **ii)** Consumable charges: Rs 0/-
- **iii)** Travel Cost (Boarding and Lodging, if any) :Rs 0/-

b. Usage of fabrication and testing facilities across the country (Fabrication Mode)

- **i)** Fabrication and testing Charges: Rs 0/-
- **ii)** Consumable charges: (if any) Rs 0/-
- **iii)** Travel Cost (Boarding and Lodging, if any): Rs 0/-

ii) Medium term Engagement: Not Applicable

a. Execution of project in any one of the Host Institution (Project Mode)

- **i)** Fabrication and or testing Charges
- **ii)** Consumable charges (if any)
- **iii)** Travel Cost (Boarding and Lodging, if any)

b. Execution of project in Multi Host Institutions (Project Mode)

- **i)** Fabrication and or testing Charges
- **ii)** Consumable charges (if any)
- **iii)** Travel Cost (Boarding and Lodging, if any)

(i) (Round-trip to the Host Institution by 2nd class (Non-AC) railway via the nearest route)

(ii) Details of User's Bank Account:

(iii)(Please send a copy of the cancelled cheque/copy of the passbook carrying all the information needed)

(iv) Beneficiary Name (User's name): Nesleena P PAN: DYVPP2982N

(v) Bank Account No. 20229505583 Name of the Branch: VADAKARA

(vi)IFSC Code: SBIN0005048

Signature of the applicant
Nesleena P

Dr. MINI MOL Menamparambath
Department of Chemistry, NITC

Signature of the guide

Details of funding requirements for characterization purposes

SL. No	Characterization	Institute with the facility	Charge per analysis (Incl. GST)	No of samples	Total amount
1	FT – RAMAN	SAIF IITM	Rs 360/-	20	7200/-
2	HR- SEM	SAIF IITM	Rs 900/-	25	22500/-
3	SEM EDS/ MAPPING	SAIF IITM	Rs 2000/-	20	40000/-
4	HR – TEM SAED	STIC, CUSAT	Rs 2000/-	15	30000/-
5	TEM EDS/ MAPPING	CeNS, Bangalore	Rs 2832	10	28320/-
6	AFM	CeNS, Bangalore	Rs 1180	10	11800/-
7	XPS	NIIST Trivandrum	Rs 3000/-	10	30000/-
8	GC- MS	SAIF- IITM	Rs 800/-	7	5600/-
9	ICPMS	STIC CUSAT	Rs 708/-	7	4956/-
10	GIWAXS	IISER Mohali	Rs 1770	7	12390/-
11	GISAXS	CLRI Chennai	Rs 1250/-	6	Rs 7500/-
			Total Rs. : 2,00,266/-		

Alternative facilities/Charges (*to be accessed in case the above mentioned facilities do not work)*

TEM EDS MAPPING	NIIST Trivandrum IISER Trivandrum	Rs 6250/- Rs 6000/-
AFM	PSG Institute of Advanced Studies, Coimbatore	Rs 1500/-
XPS	IIT Kanpur	Rs 3000/- + 18% GST
GC- MS	NIIST Trivandrum	Rs 780/-
GISAXS	IISER Mohali	Rs 1500/- +18% GST

Signature of the applicant

Dr. MINI MOL Menamparambath
Department of Chemistry, NITC
Signature of the Guide