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Development of Multifunctional Leather via Ionic Liquid-Mediated Polymerisation of Aniline

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Presented by

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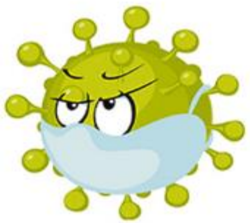
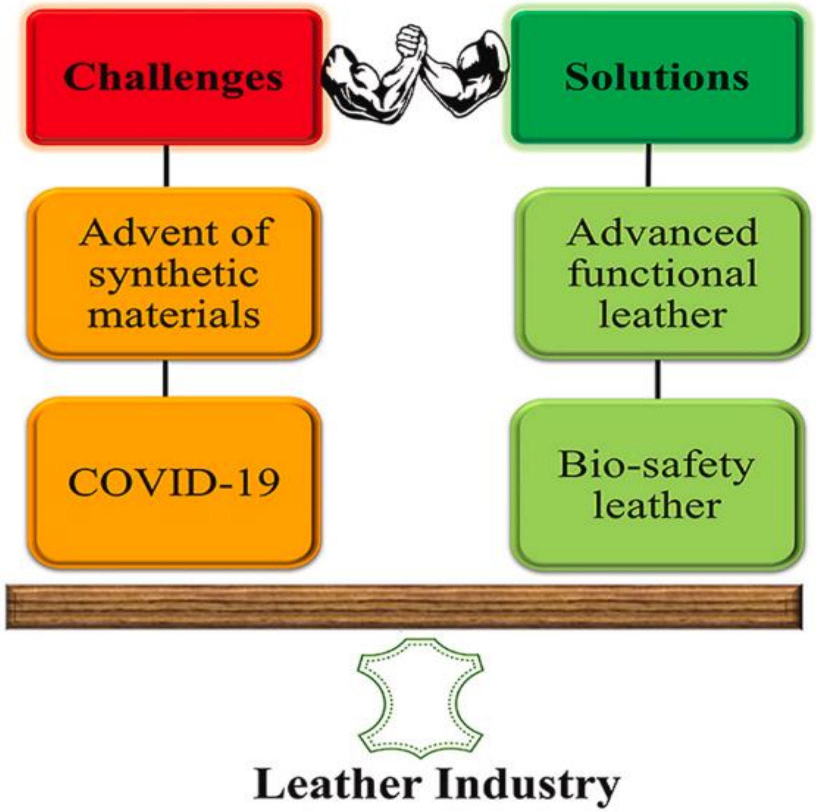
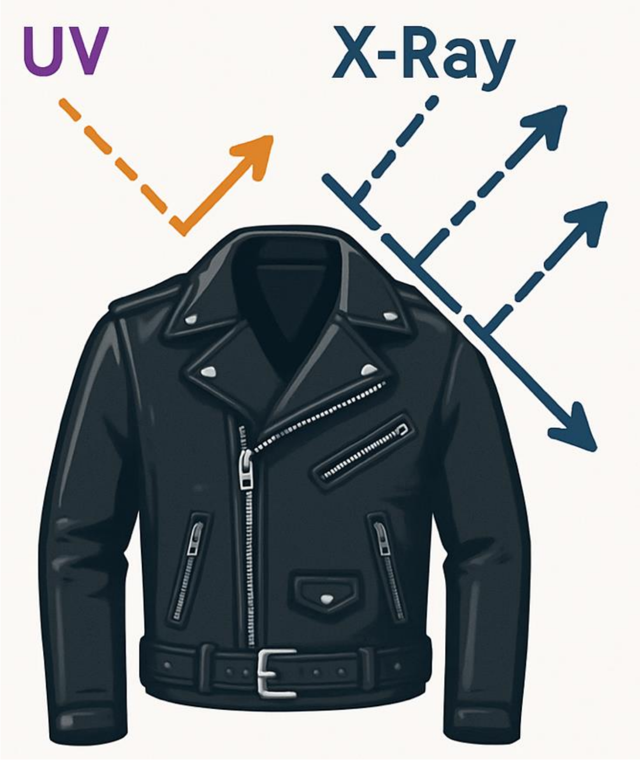
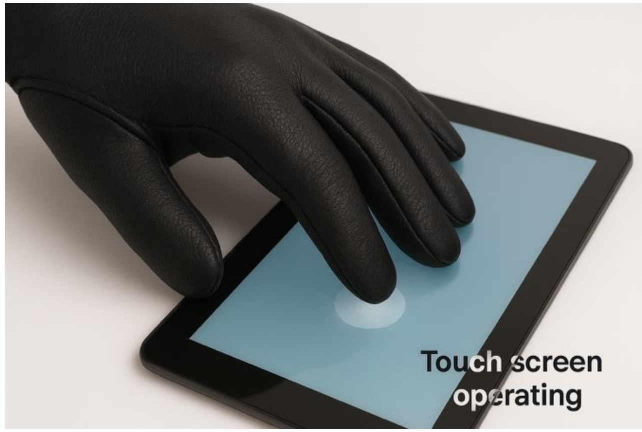
Problem statement

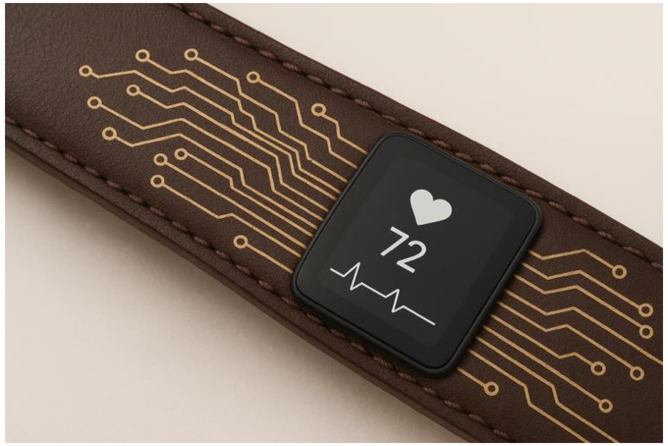




What is the need for Conductive Leathers?

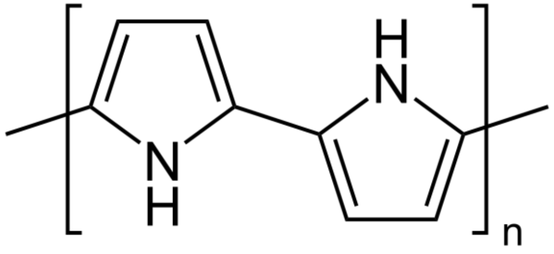






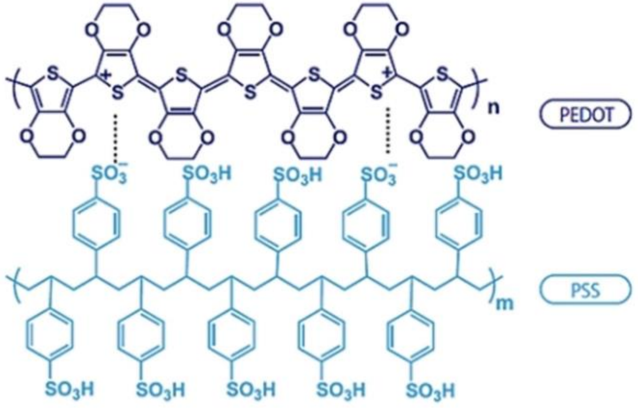
- **Human–machine interfaces** – Facilitates touch-sensitive or gesture-control surfaces in automotive and consumer products.
- **Smart wearables** – Enables integration of sensors, circuits, and electronics into fashion and protective gear.
- **Electrostatic discharge (ESD) protection** – Prevents static build-up, useful in safety footwear and industrial gloves.
- **Heated leather products** – Allows incorporation of heating elements in seats, apparel, and accessories.
- **EMI shielding** – Provides protection against electromagnetic interference in specialised applications.

Current available technologies



Polypyrrole and its composites

1. Langmuir 2025, 41, 15, 9740–9752
2. ACS Appl. Bio Mater. 2025, 8, 8, 6808–6816
3. Ind. Eng. Chem. Res. 2014, 53, 47, 18209–18215

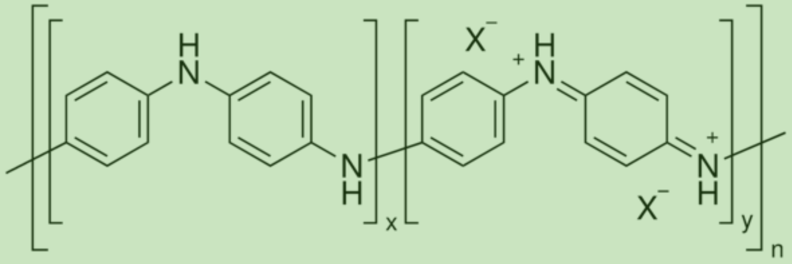


M/s. Nagase ChemteX Corporation

Chemical methods

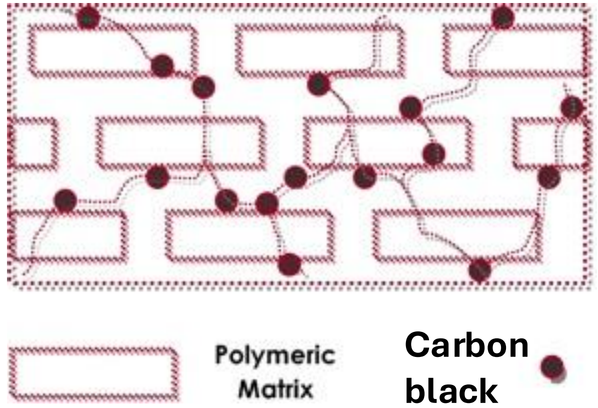
1. Conductive Polymer Coating
2. Metallic Coating / Metallization
3. Carbon-based Incorporation
4. Conductive Nanoparticle Coatings
5. Plasma Treatment & Surface Functionalization
6. Printing Techniques

Graphene - J. Mater. Chem. A, 2023,11, 11773-11785
Laser ablation – Adv Elec Mat, 2020, 6, 2000549



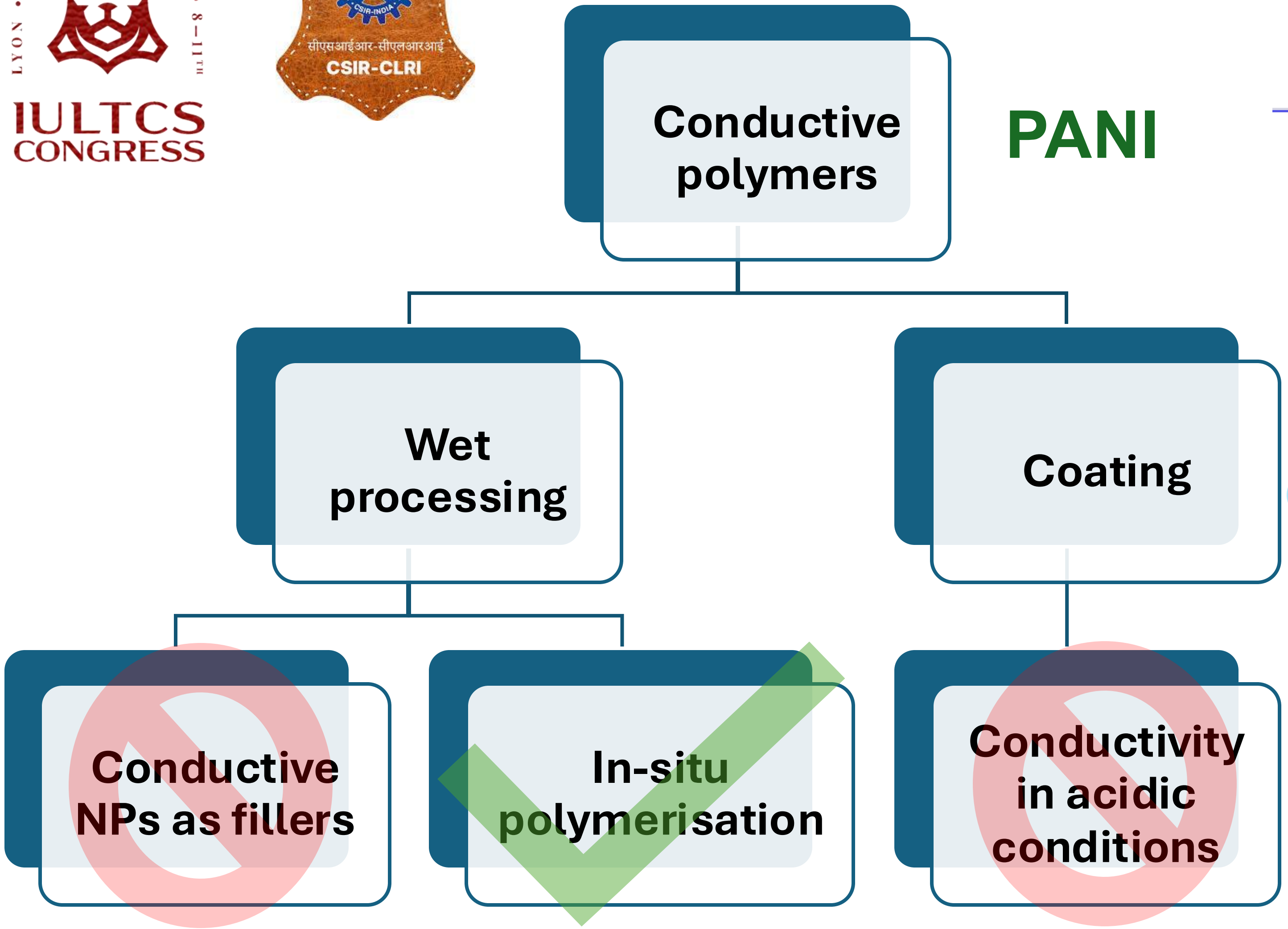
Polyaniline

Syn Met.2022, 291, 117191

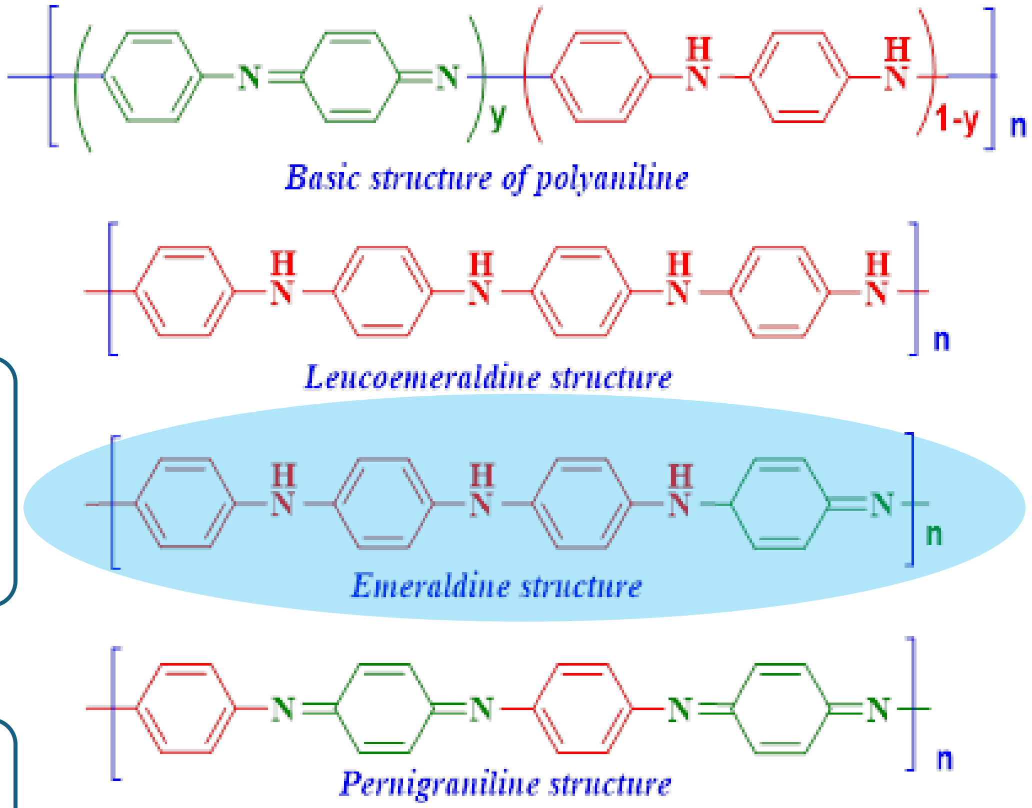


Nano Ex. 2020, 1, 010032

Process Methodology



PANI



Different Structural forms of Polyaniline

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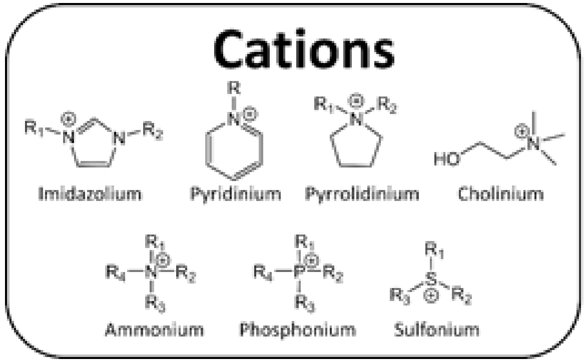
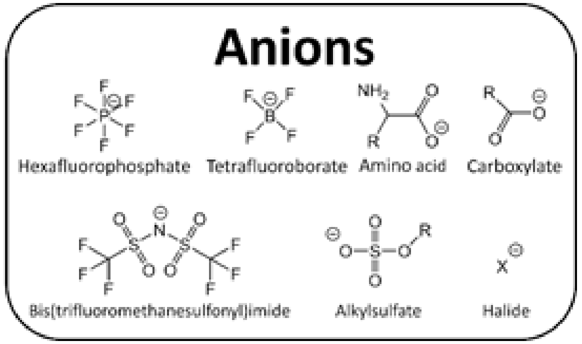
What are Ionic Liquids (ILs)?

➢ **Ionic liquids are salts that remain in liquid state at or near room temperature**, composed of bulky organic cations (like imidazolium, pyridinium, ammonium) and various anions (like BF_4^-, PF_6^-, NTf_2^-).

- ✓ Green solvents
- ✓ Catalysis
- ✓ Electrolytes (batteries, supercapacitors, fuel cells)
- ✓ **Polymer synthesis & templating**
- ✓ Enzyme stabilization
- ✓ Drug delivery
- ✓ Biomass dissolution
- ✓ Nanomaterials synthesis
- ✓ Lubricants

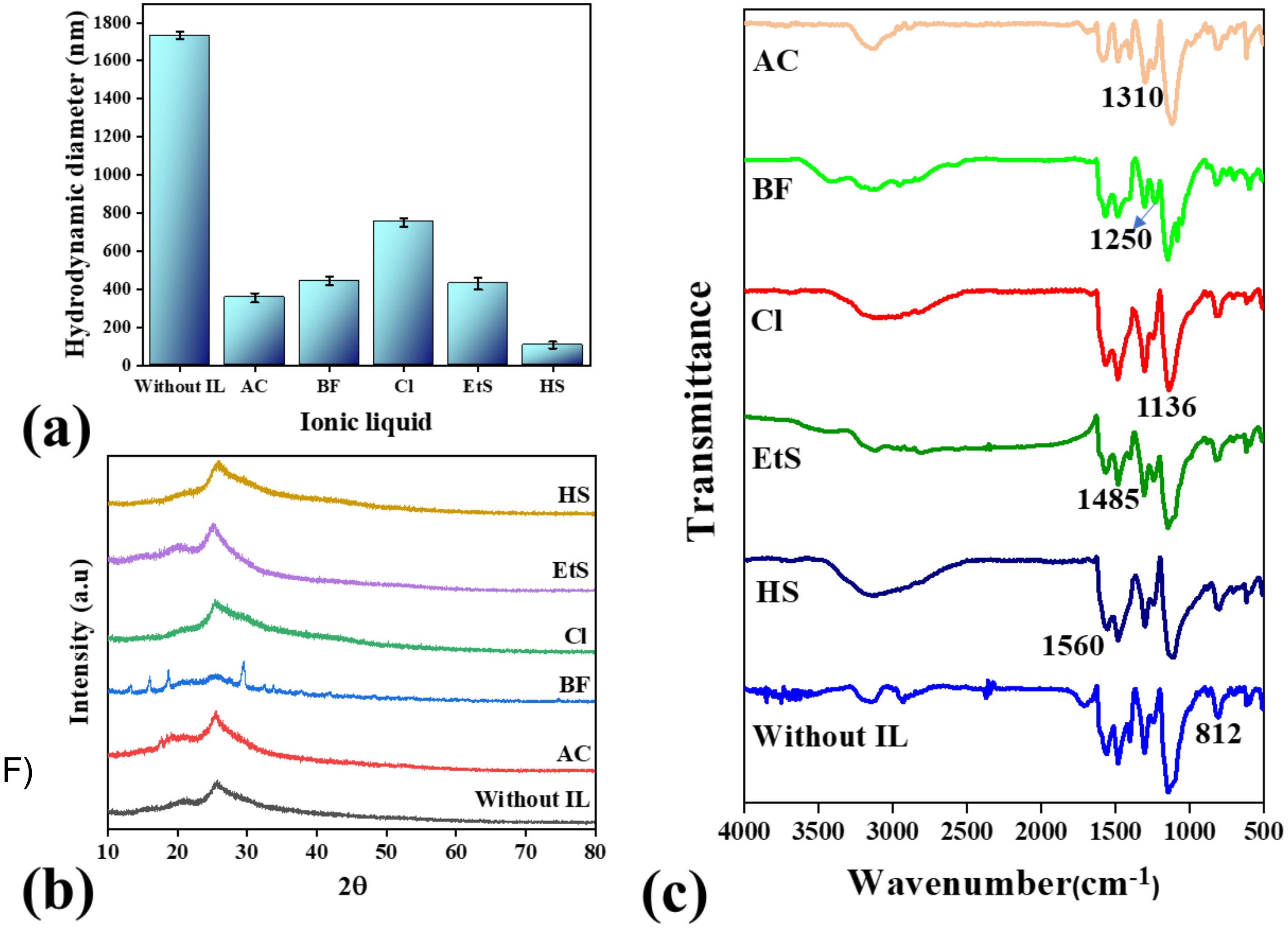
- ❖ **Self-Assembly**
- ❖ **Nanoconfinement**
- ❖ **Electrostatic Interactions**
- ❖ **Morphology Control**
- ❖ **Stabilization**





ILs vs Aniline Polymerisation

(a) Influence of different ILs on the hydrodynamic diameter of PANI. (b) XRD and (c) FTIR spectra of PANI synthesised using different ILs.

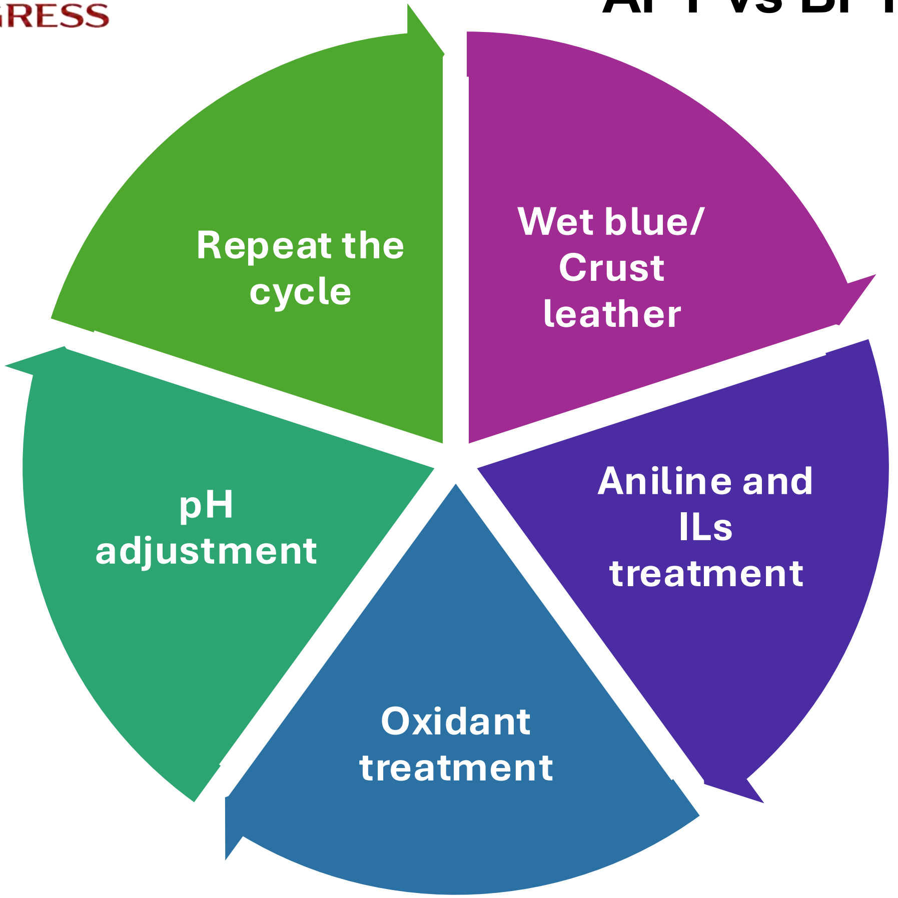


Choice of ILs

1-Butyl-3-methylimidazolium acetate ([bmim]Ac)
1-Butyl-3-methylimidazolium tetrafluoroborate ([bmim]BF)
1-Butyl-3-methylimidazolium chloride ([bmim]Cl])
1-ethyl-3-methylimidazolium ethylsulfate ([emim]EtS)
1-methylimidazolium hydrogensulfate ([mim]HS)

Process followed

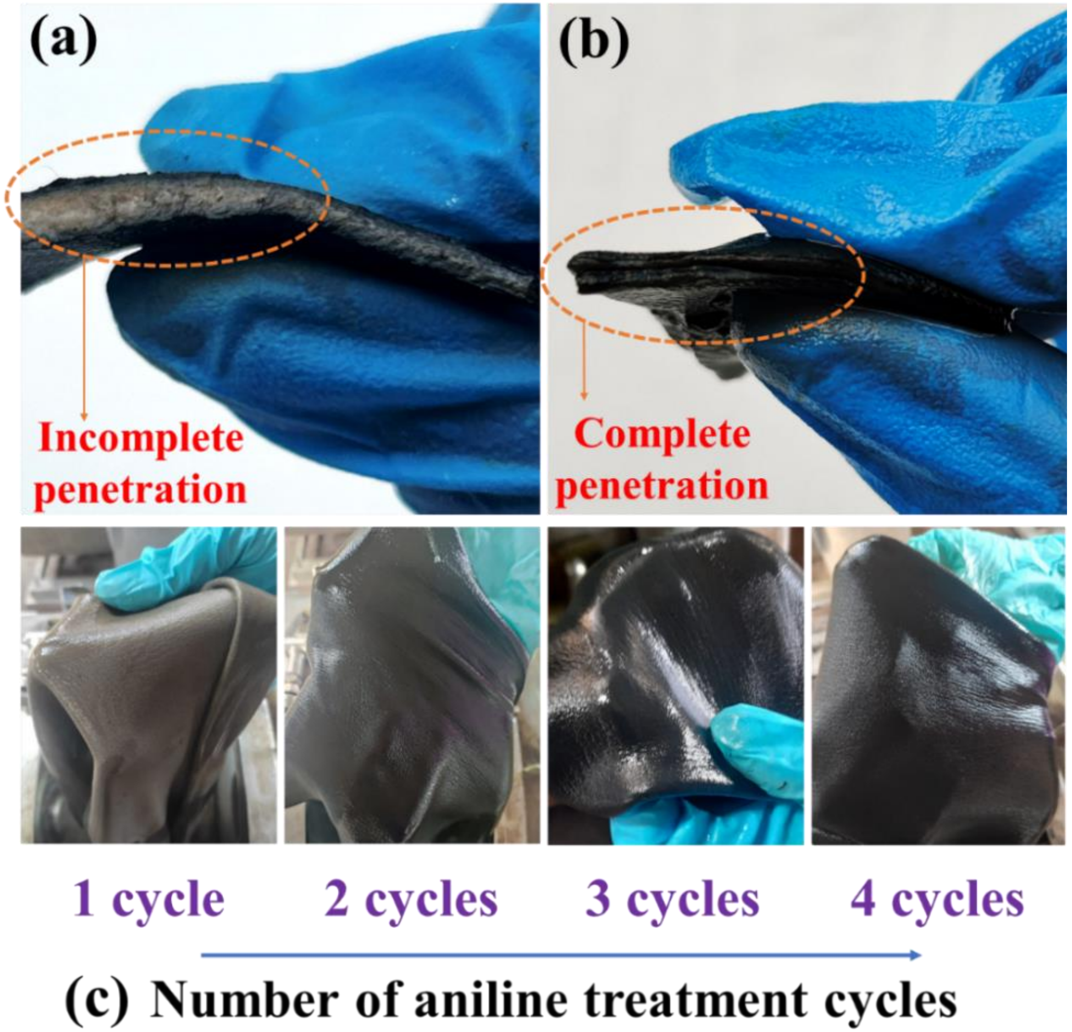
APT vs BPT

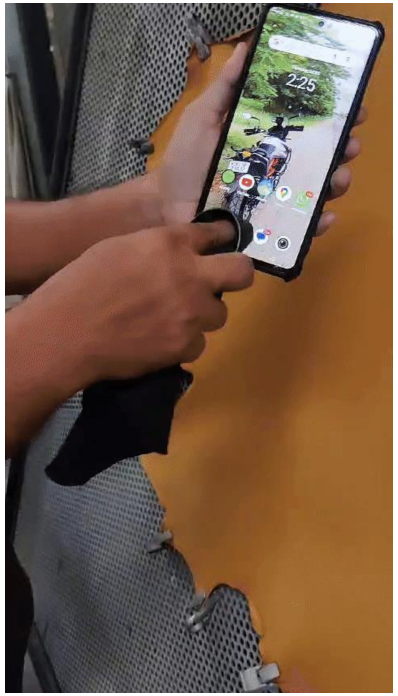


Process name	Chemical used	% offer	Duration	Comments
Raw material	Chrome tanned sheep leather for BPT process Sheep post-tanned leather for APT process Shaving thickness = 0.7 ± 0.2 mm			
Wet-back	Water	150		
	Wetting agent	0.5	8 hrs	Ensure complete rehydration of the leather matrix.
In-situ polymerization	Water	50		
	Aniline hydrochloride	2.5		
	Ionic liquid*	X	8 hrs	
	Ammonium persulfate	3.5	2 hrs	Diluted 1:10 with water Given as 4 feeds at 30 mins intervals
	The same is repeated as per the number of cycles of aniline treatment.			
Washing	Water	150	15 mins	Wash well twice to remove any unreacted materials
Piled overnight and taken up for post-tanning process the next day. In the case of APT system, the post-tanned leathers are taken and processed similarly, and the pH of the final leather after the completion of the in-situ polymerization process is adjusted to 4.0 using sodium bicarbonate. *X = Ionic liquid is added 1:0.5 mole ratio based on aniline offer.				

Aniline treatment – Leather process optimisation

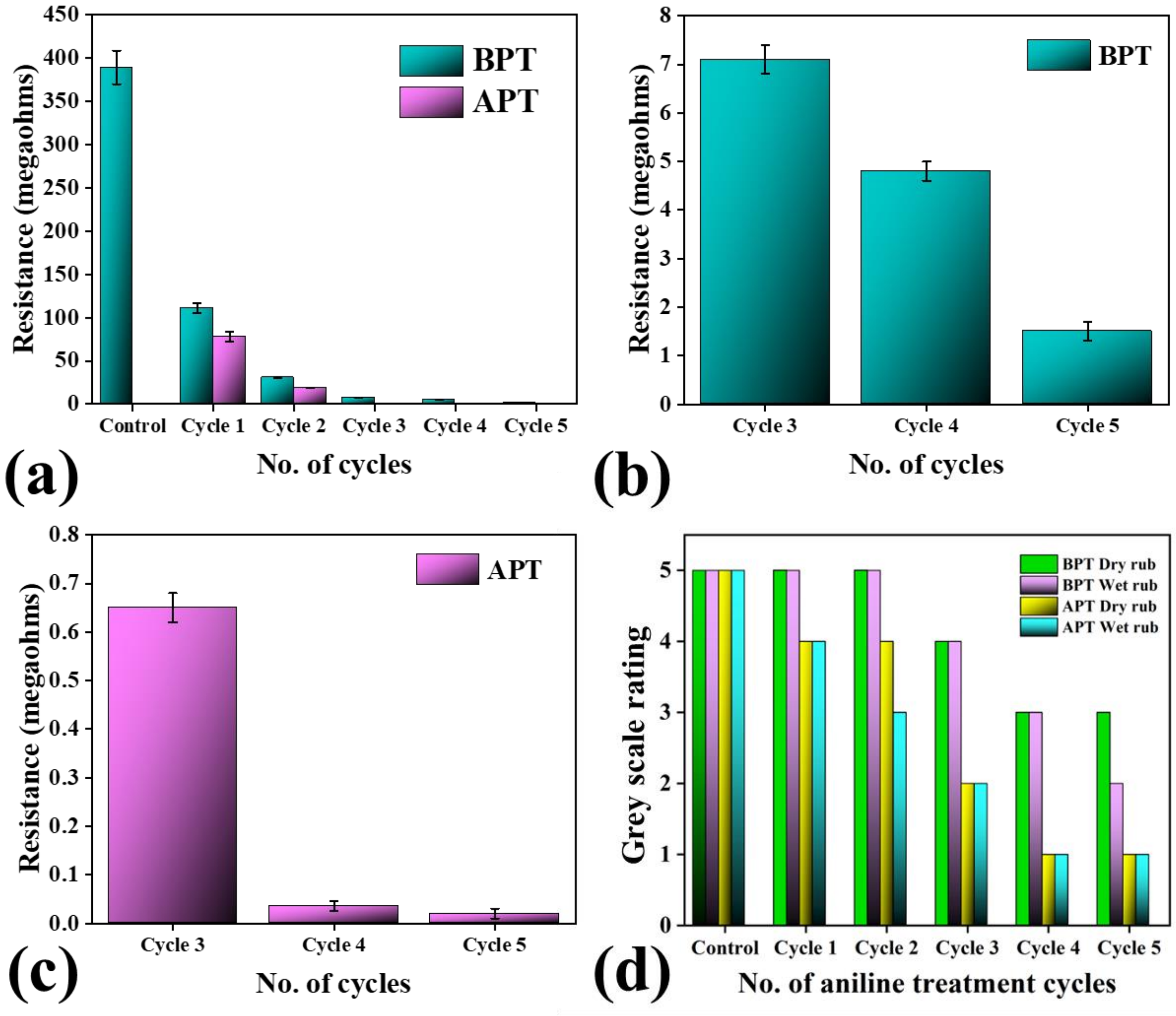
Photographic images (a) cross-section of aniline-treated leather without IL, (b) cross-section of aniline-treated leather with HS-IL and (c) Coloration of leather post-in-situ polymerization of aniline.



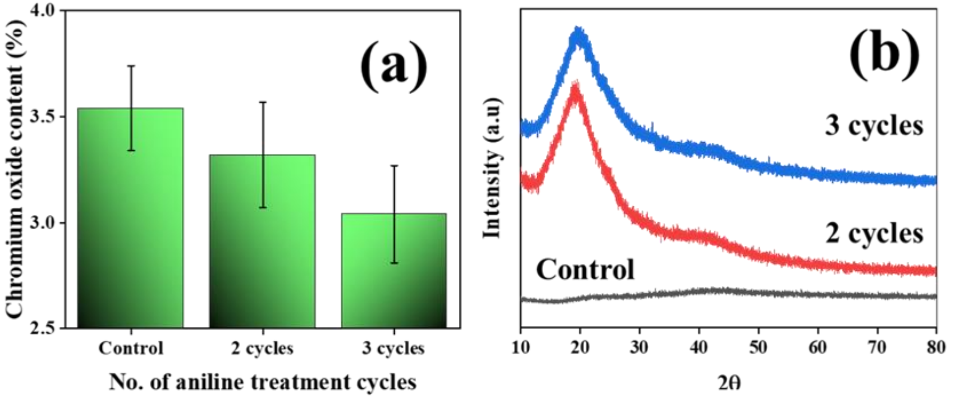


Aniline cycles vs Conductivity vs Fastness

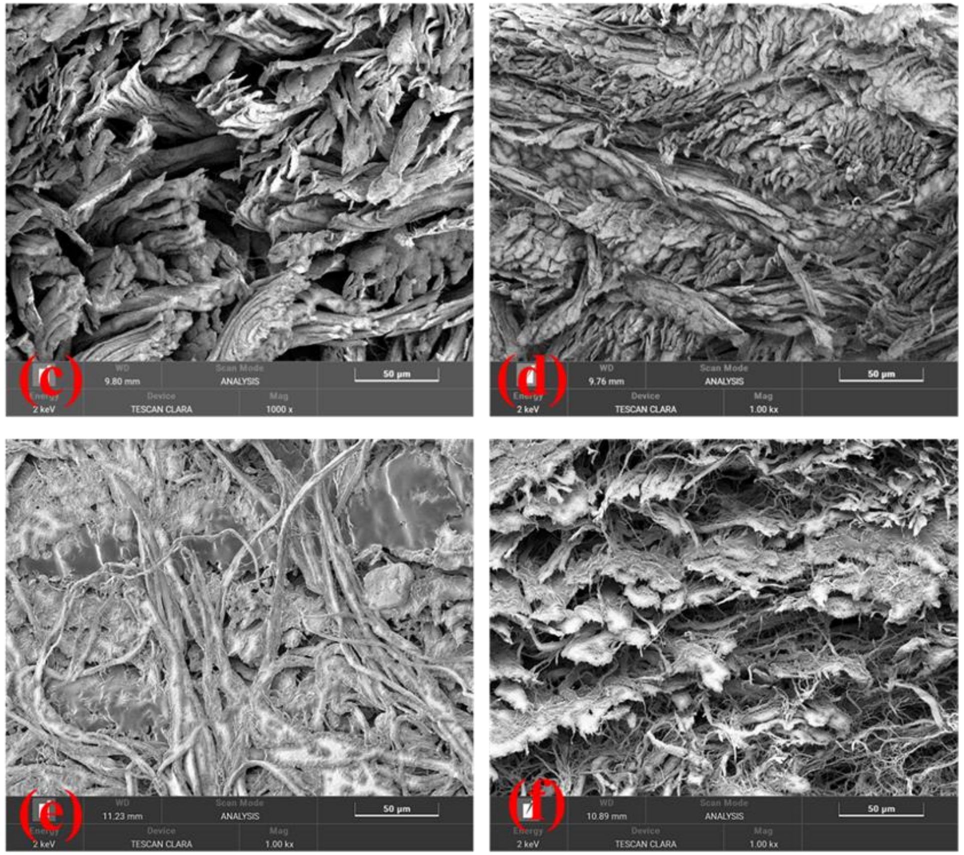
Impact on (a-c) Electrical resistance and (d) Color fastness test (rubbing at dry and wet conditions) upon increasing the number of aniline treatment cycles.

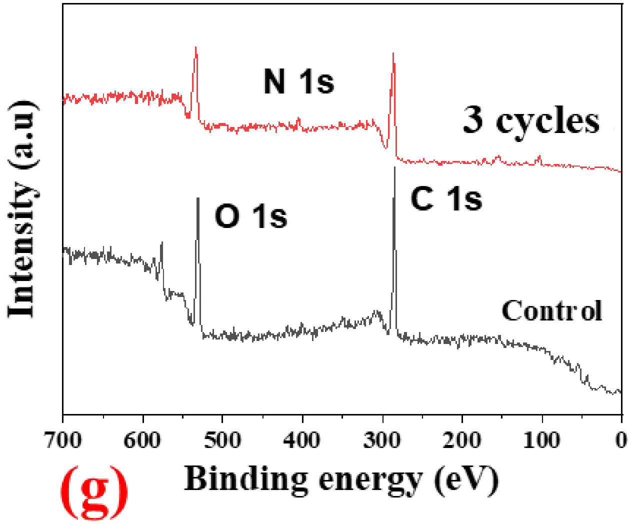


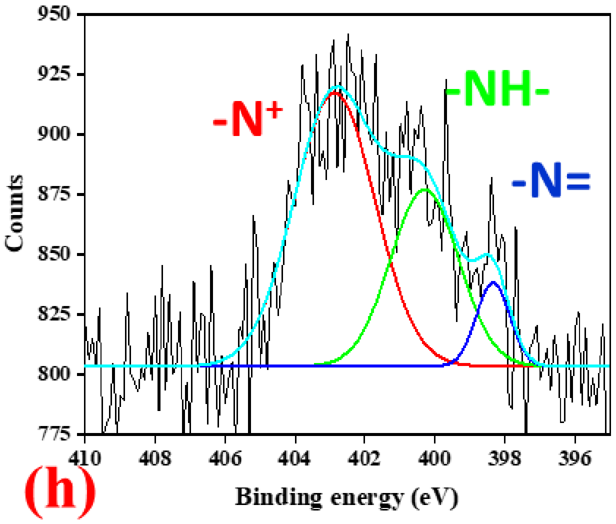
Characterization of BPT-PANI leathers



(a) Impact of aniline treatment on chromium oxide content of leathers, (b) PXRD spectra of control and aniline treated leather, SEM images of cross-section of (c & d) control leather, (e & f) aniline treated leather, (g) Survey XPS spectra of control and experimental leathers and (h) N1s XPS spectra of In-situ polymerised PANI treated leather.







Physical properties of PANI-treated leathers

Property	Control leather	HS-IL aided PANI BPT-leather	
		Cycles 2	Cycles 3
Tensile Strength (N/mm^2)	21.4 ± 1.3	19.1 ± 1.7	17.6 ± 2.1
Tear Strength (N/mm)	66.2 ± 2.8	52.8 ± 2.6	45.7 ± 2.3
Elongation at break (%)	68.1 ± 3.1	60.1 ± 3.5	58.9 ± 4.2
Lastometer ball burst test Load at grain crack (kg) Distention at grain crack (mm)	 17.8 ± 1.2 11.4 ± 0.9	 15.1 ± 1.1 10.9 ± 1.1	 14.8 ± 0.9 10.5 ± 1.3
Mass per unit area (g/m^2)	344.5 ± 4.5	409.7 ± 5.8	424.6 ± 4.9
Color fastness to light from a xenon Arc	Natural color*	4/5	4/5
Water vapour permeability, absorption and coefficient ($mg/cm^2/hr$)	11.4 ± 1.8	9.1 ± 2.2	8.3 ± 1.6

*Light fastness could not be measured since no coloring substance was used.

Organoleptic and Flame retardant properties of PANI-treated leathers

Sample	After flame glow (s)	Smoke-off time (s)	Flame distance (mm)	Flammability degree (mm/min)	% improvement in Flammability
Control	12.5 ± 1.3	13 ± 2.5	6.4 ± 1.2	25.6 ± 4.8	-
Cycle 2	5 ± 1.6	6 ± 1.9	1.6 ± 0.5	6.4 ± 2.0	75.0%
Cycle 3	0	2 ± 1.1	1.1 ± 0.4	4.4 ± 1.6	82.8%

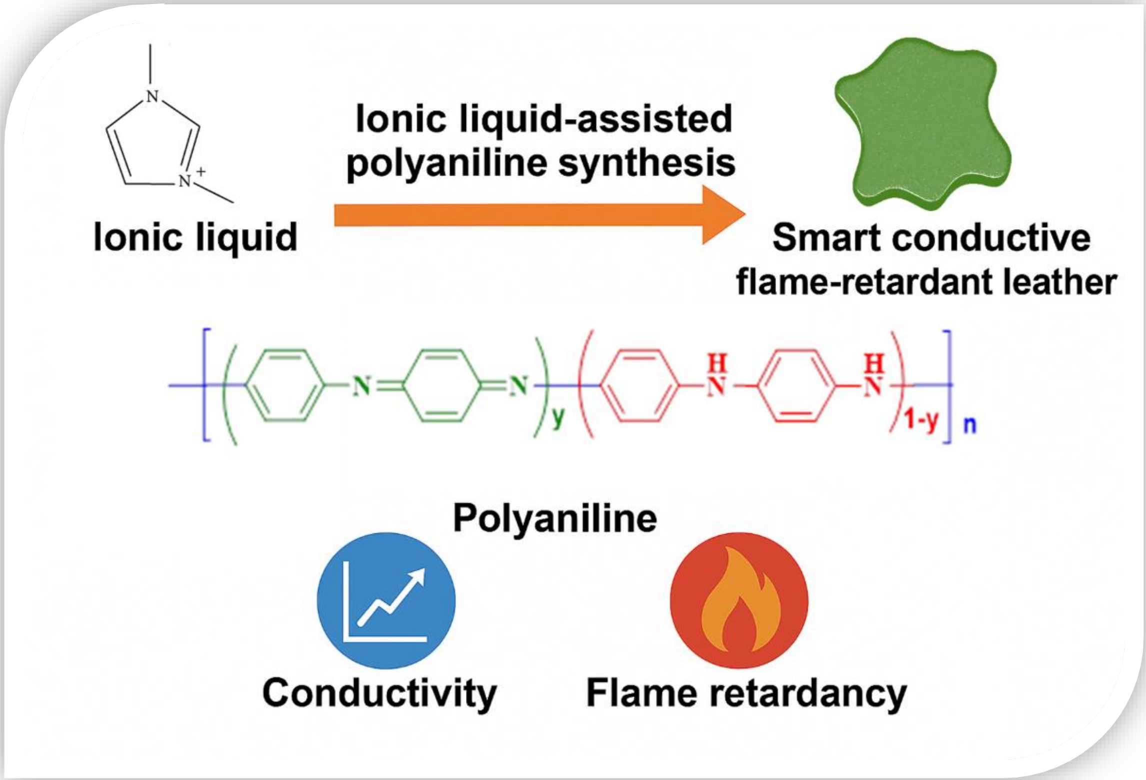
Property	Control	HS-IL aided PANI BPT-leather	
		Cycle 2	Cycle 3
Grain smoothness	9	8	8
Fullness	6	7	8
Softness	8	8	7
Stretchiness	8	7	7
Color uniformity*	-	6	8
Resistance to color bleeding*	-	8	8
Sensitivity to touch-screen devices	1	6	8

All the properties were rated out of 10 by leather experts.
* Color uniformity and resistance to color bleeding could not be measured for control leathers since no coloring substance was used.

Effluent characteristics from HS-IL aided PANI BPT-leather making process

Parameters	Control	HS-IL aided PANI BPT-leather	
		Cycle 2	Cycle 3
COD (mg/L)	7200 ± 189	12800 ± 257	15200 ± 642
TS (mg/L)	13814 ± 247	16048 ± 351	17765 ± 856
TDS (mg/L)	13390 ± 420	14942 ± 458	16323 ± 497
TSS (mg/L)	424 ± 84	1106 ± 89	1442 ± 102
Total Cr (mg/L)	24.1 ± 2.8	69.5 ± 8.1	106.5 ± 11.2
Cr (VI) (mg/L)	BDL	47.7 ± 6.9	69.4 ± 5.1
Cr (VI) (mg/L) after sodium metabisulphite addition	BDL	BDL	BDL

Summary of the research work



- Demonstrated size-controlled in-situ polymerization of aniline using Ionic Liquids as templates.
- Resistivity values of leather reduced from 389.4 MΩ to 1.5 MΩ.
- Demonstrated enhanced flame-retardant properties, with an 82.8% reduction in flammability degree.
- Developed touch-screen-friendly leathers.

Acknowledgements

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Thank You!!!