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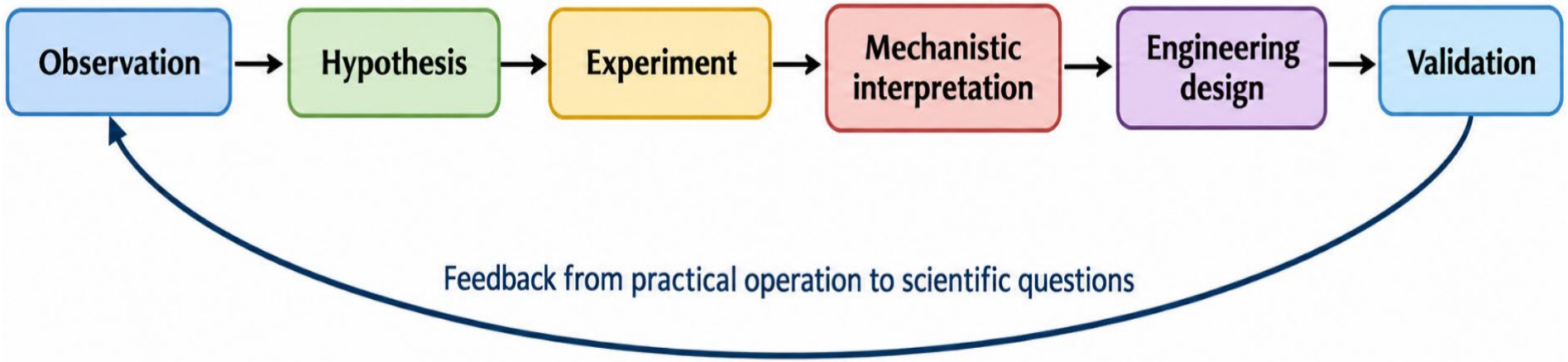


ADVANCED MATERIALS, PLASMA TECHNOLOGIES AND ANALYTICAL SCIENCES FOR SUSTAINABLE INDUSTRIAL DEVELOPMENT

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From physics to deployable technology



Core message

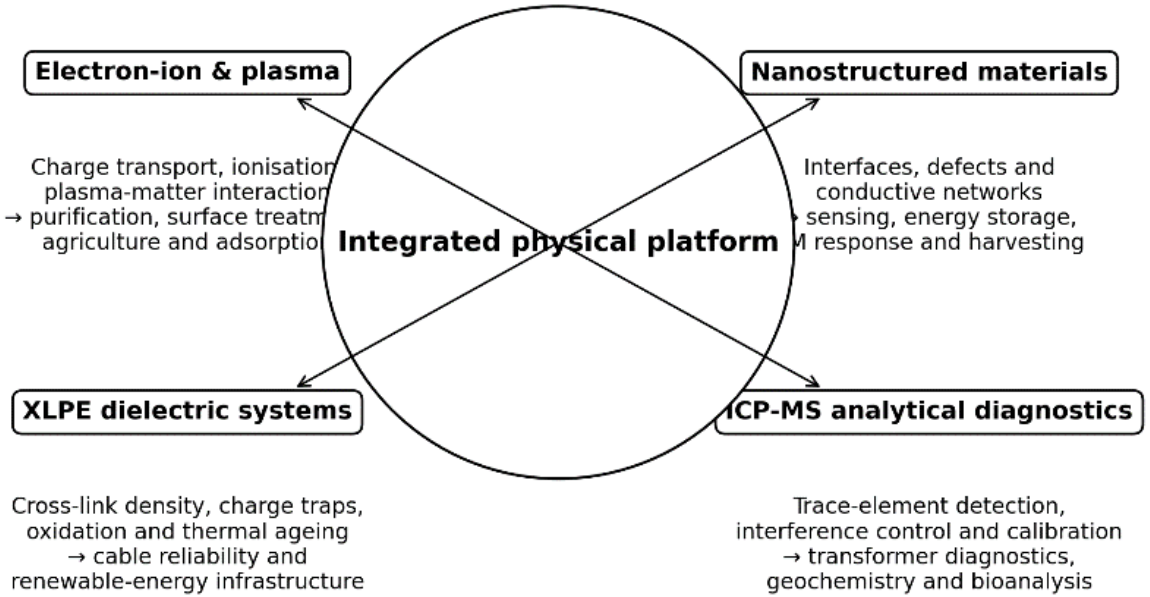
The paper organizes four research directions using one feedback cycle: feedback cycle: observation → hypothesis → experiment → interpretation → engineering design → validation.
Practical use is treated as part of the scientific loop because it returns new questions for mechanism refinement.
The common goal is not isolated measurement, but controlled, reproducible industrial function.

Four reviewed directions

Electron-ion and plasma technologies
Nanostructured functional materials
XLPE dielectric systems
ICP-MS-based analytical diagnostics

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Integrated physical platform



Why the four areas belong together

Plasma treatment modifies surfaces and media; the changes must be must be characterized and validated.
Nanostructured materials use interfaces, defects and conductive networks to produce sensing, storage and harvesting functions.
XLPE reliability links molecular structure and ageing to cable lifetime and grid reliability.
ICP-MS provides a verification layer through trace-element detection, calibration and matrix correction.

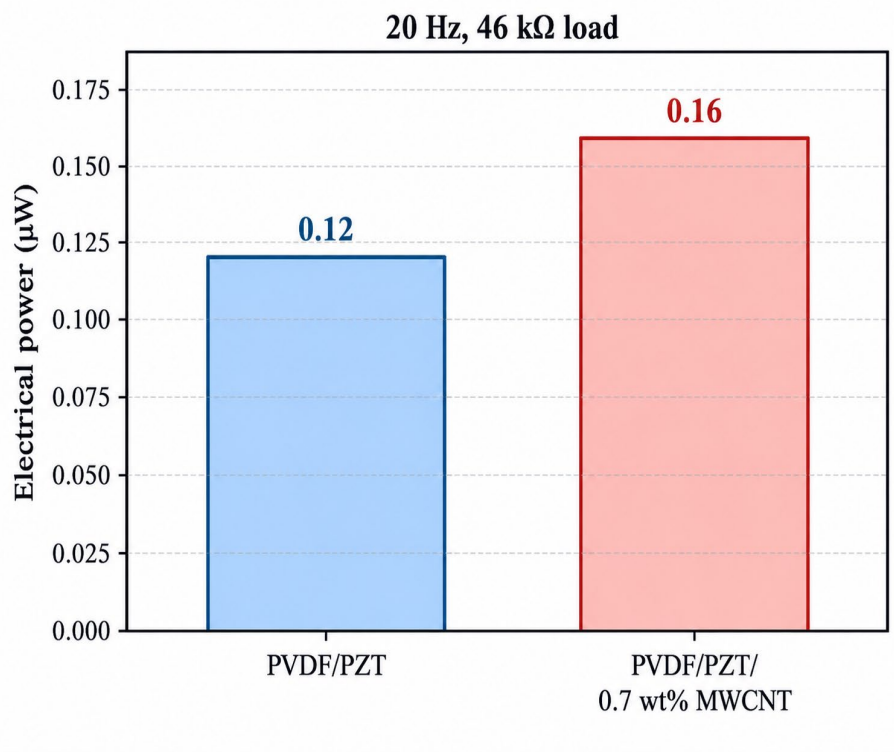
4 complementary research directions

1 continuous research-to-technology cycle

3 technology transfer priorities

1 sustainable industrial platform

Representative outcomes reported in the paper



Nanogenerator performance

PVDF/PZT/MWCNT reached 0.16 μW versus 0.12 μW baseline under 20 Hz and 46 kΩ load.
The reported increase is about one third, showing the role of conductive-network engineering.

Broader outcomes

Electron-ion programme: more than 220 publications and about 20 patents reported in the source material.
ICP-MS work: trace elements in transformer oils, geological cores and biological fluids used as diagnostic information.
Geochemical ICP-MS: core samples deeper than 3,600 m support stratigraphic and hydrocarbon-migration interpretation.
XLPE studies identify cross-linking, voids, charge trapping, oxidation and thermal stress as key ageing determinants.

Interpretation: strongest technological results appear when mechanism, mechanism, controllable process parameters and analytical verification verification are connected.

Priorities for industrial transfer

1. Pilot-scale comparability

Report energy input, gas composition, residence time and treated-material throughput together.
Move from peak laboratory effects toward reproducibility, stability and manufacturability.

2. Analytical traceability

Document sample preparation, calibration, blank correction and uncertainty consistently.
Use ICP-MS and complementary methods as shared verification across materials and process studies.

3. System integration

Combine treatment stage, in-line sensing and periodic laboratory validation.
Support condition-based maintenance and evidence-based asset management.

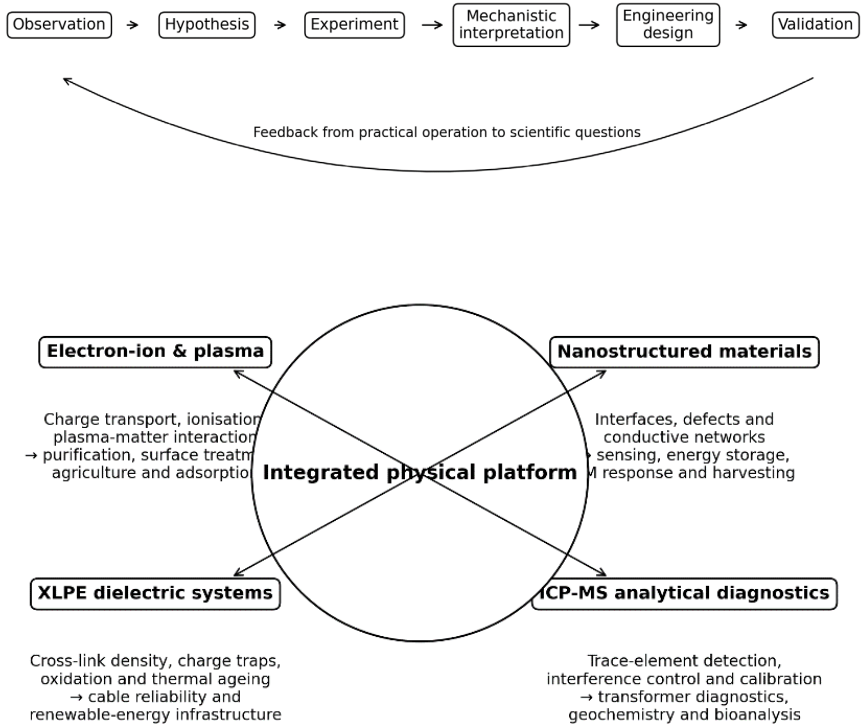
Sustainability indicators should be quantitative

Energy consumption per treated mass or volume
Contaminant reduction, lifetime extension and material recovery
Maintenance reduction and total process cost

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Main takeaways

Electrical-discharge studies progress from ionisation and stability toward controlled plasma-assisted adsorption, purification, surface modification and environmental treatment.
Nanotechnology connects interface engineering with sensing, energy storage, electromagnetic response and vibration-energy harvesting.
XLPE research shows that dielectric reliability depends on molecular architecture, void formation and ageing mechanisms.
ICP-MS turns trace-element measurement into diagnostic information for assets, geological samples and biological matrices.



Observation must become mechanistic understanding before it can become a robust engineering solution.