Universidade de Brasília

Instituto de Física

Laboratory of Instrumentation in Nanomaterials and Sensors (LabINS)

LabINS

Catalyzing Change, Layer-by-Layer

Scalable Synthesis of van der Waals 2D Materials for the Hydrogen Evolution Reaction (HER)

Liquid-Phase Exfoliation & Automatic Mechanical Exfoliation (AME)

Jorlandio F. Felix[1,2]

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[2] Visiting Researcher, University of Sunderland, UK

jorlandio@unb.br

UN environment programme

CTCN

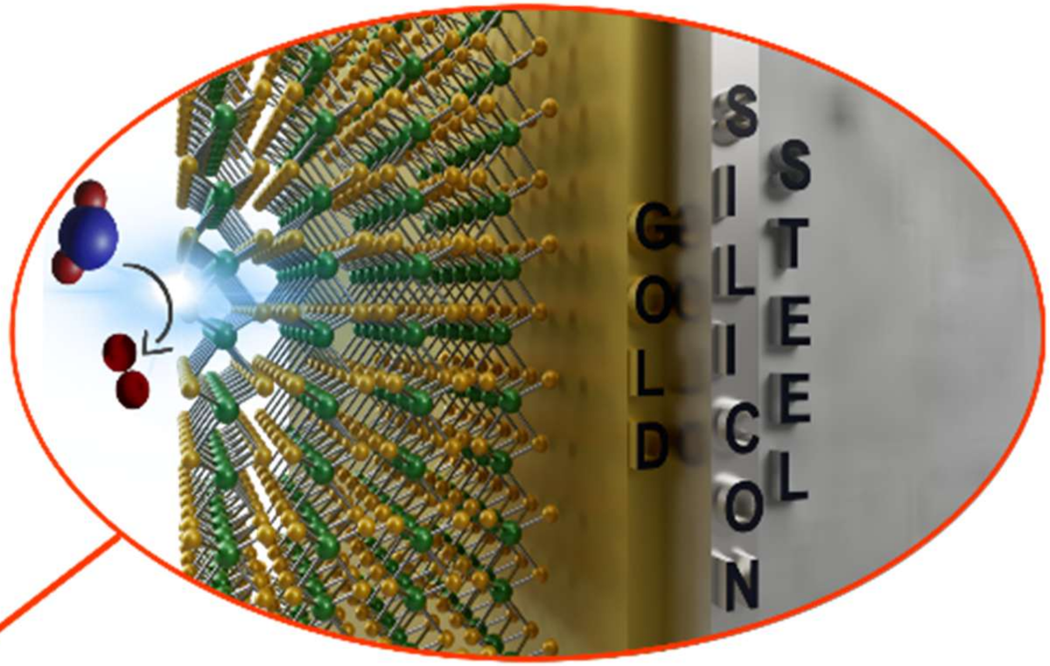
UN Climate Technology Centre & Network

UNFCCC Technology Mechanism

UnB

Outline

- Introduction
  - UnB, Institute of Physics & LabINS
- Van der Waals materials
  - TMDs & deposition techniques
  - AME & AFM characterization
- Results: HER
  - Exfoliated TMD thin films
  - γ-rays & magnetic-field effects
- Energy & Outlook
  - Hydrogen projects & initiatives
  - Collaboration & final remarks



J F. R. Marroquin.., J F. Felix, Chemical Engineering Journal, 498,2024,155498.

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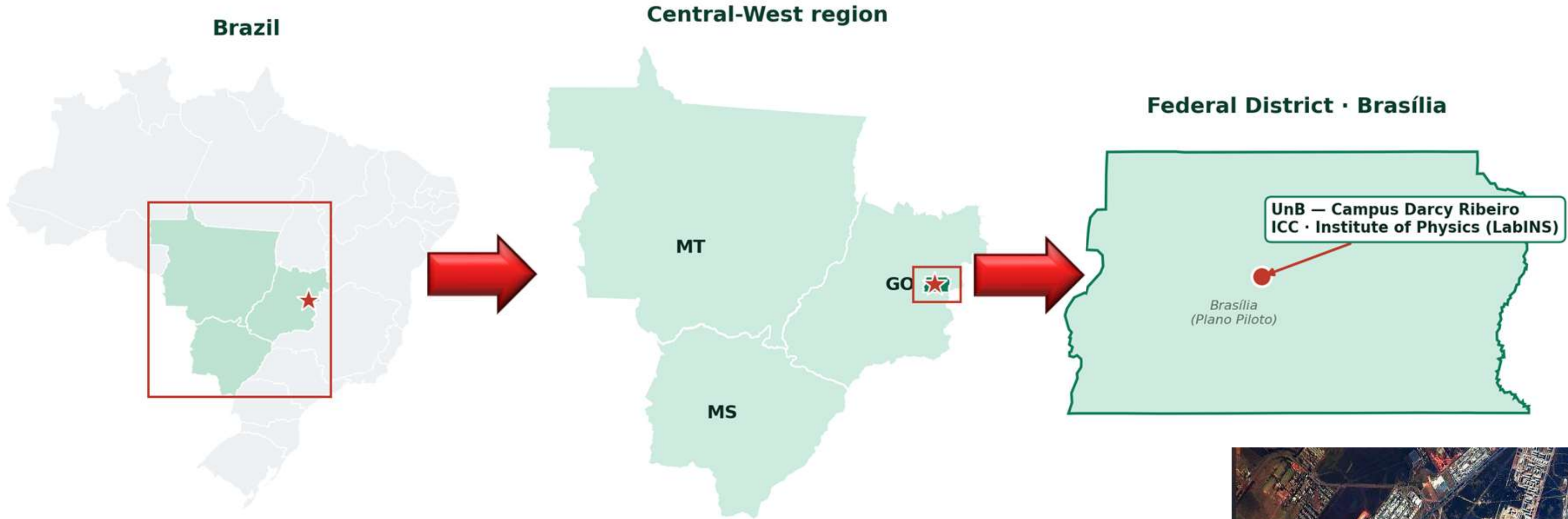
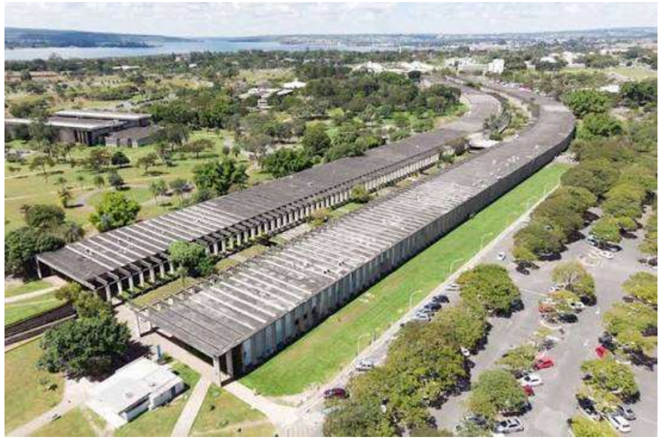
Where we are: University of Brasília (UnB) – Institute of Physics





Central Science Institute (ICC) — Darcy Ribeiro Campus, UnB

LabINS

Russian cosmonaut Sergey Ryazanskiy from the ISS (International Space Station)

LabINS - Research Group

LabINS Research Group — Institute of Physics, University of Brasília (2026)

OUR TEAM

14

researchers

- **3** Professors
- **3** Post-docs
- **1** PhD candidate
- **2** Master's students
- **4** Undergrad (IC) researchers
- **1** Lab technician

One master's student is not in the photo.

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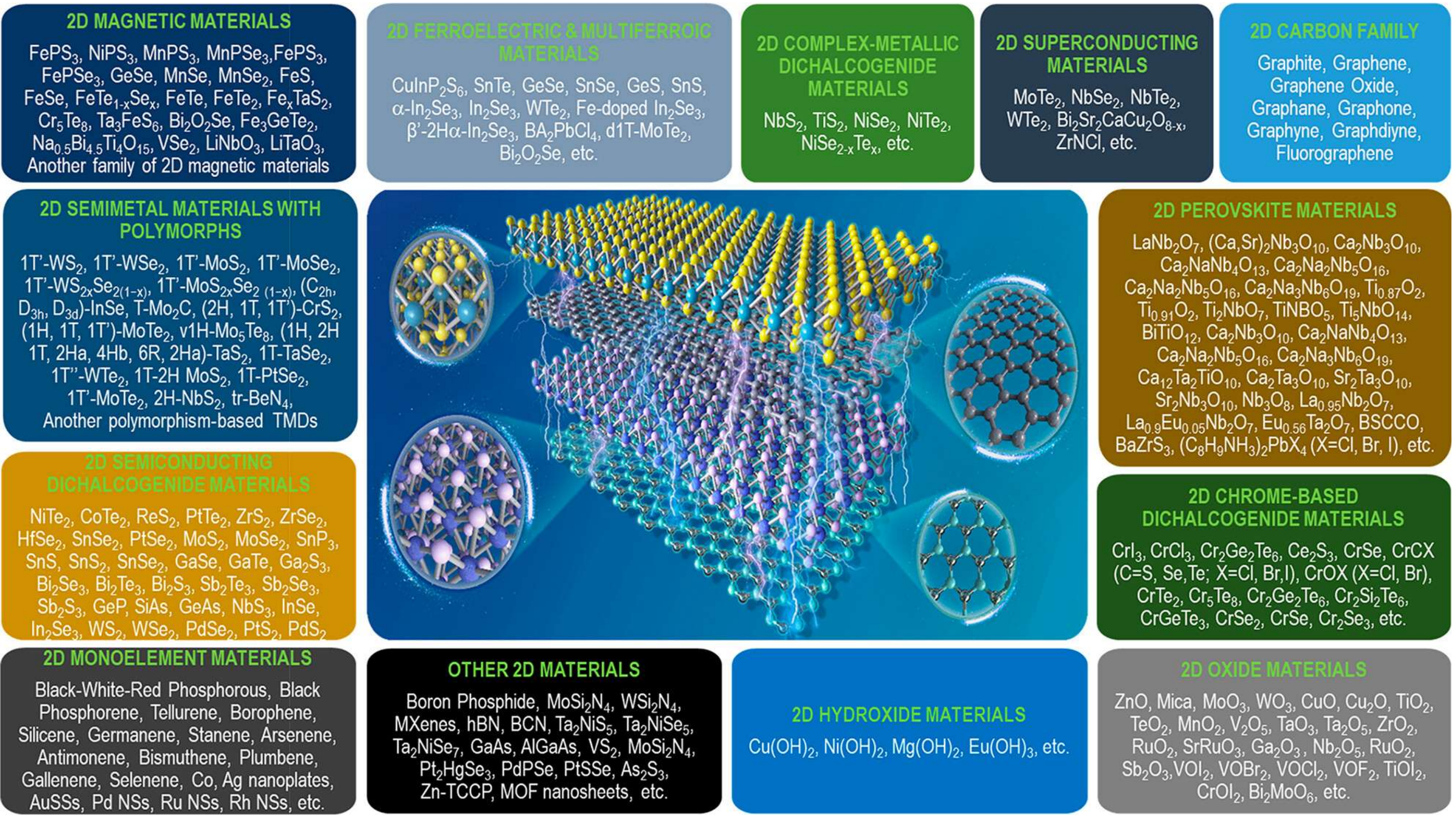
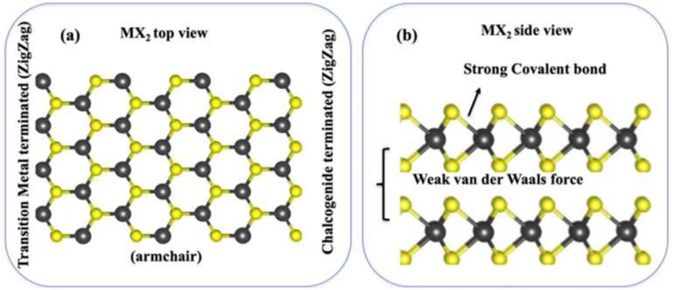
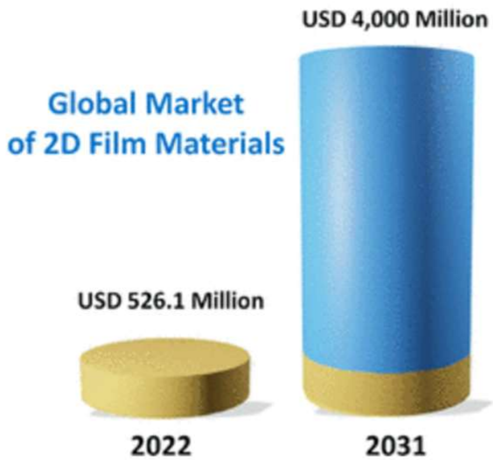
Van der Waals (vdWs) materials



An emerging grand family of 2D films that has been discovered in both experimental synthesis and theoretical computation in the 21st century. [*Chem. Rev.* **2022**, 122, 6, 6514–6613]



. Sci Rep 10, 1648 (2020)



Global market forecast of 2D film materials between 2022 e 20231
[*ACS Nano* 2024, 18, 23, 14841-14876]

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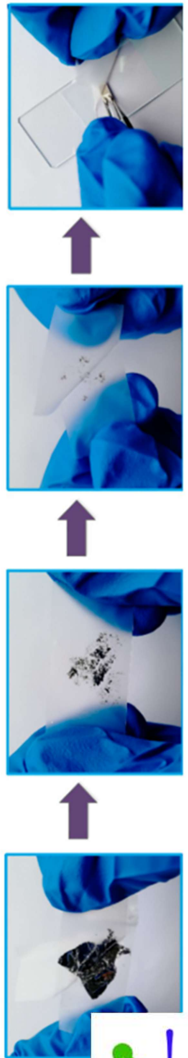
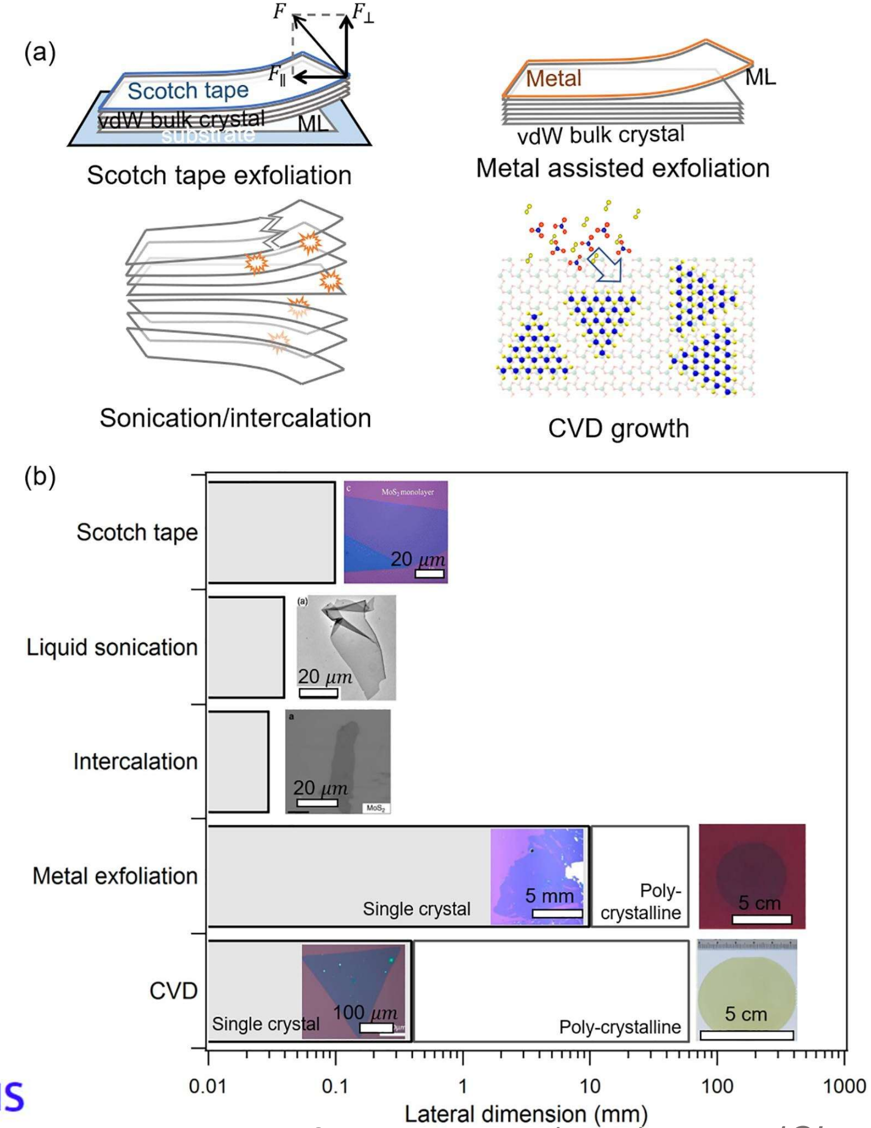
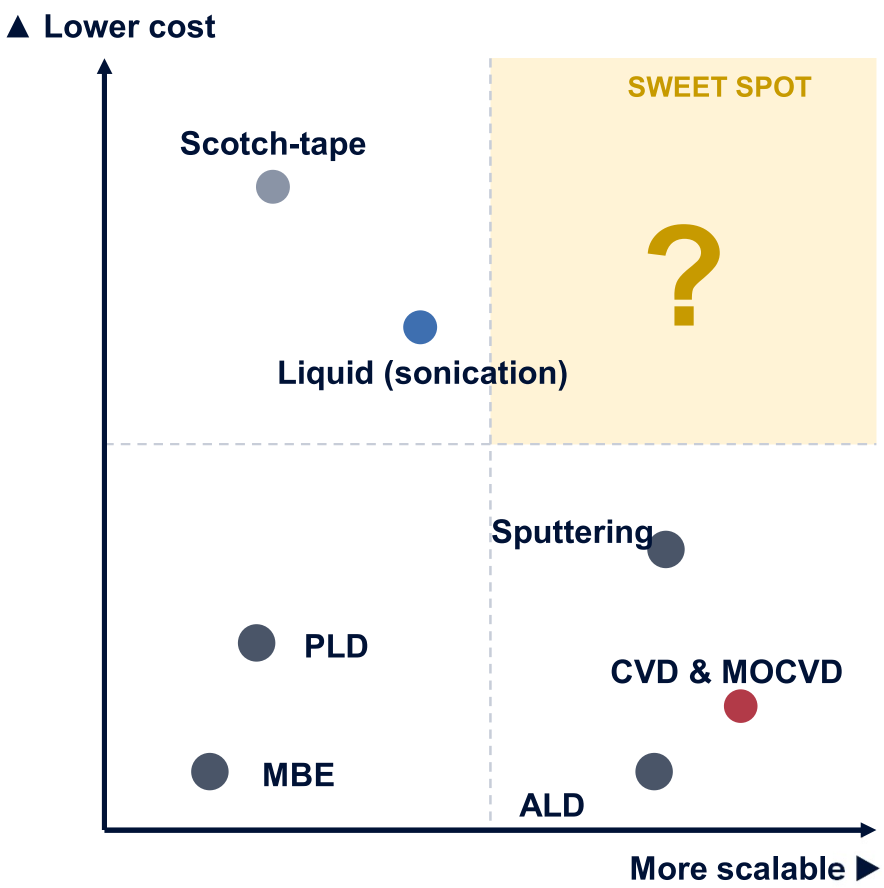
vdWs materials: Deposition Techniques







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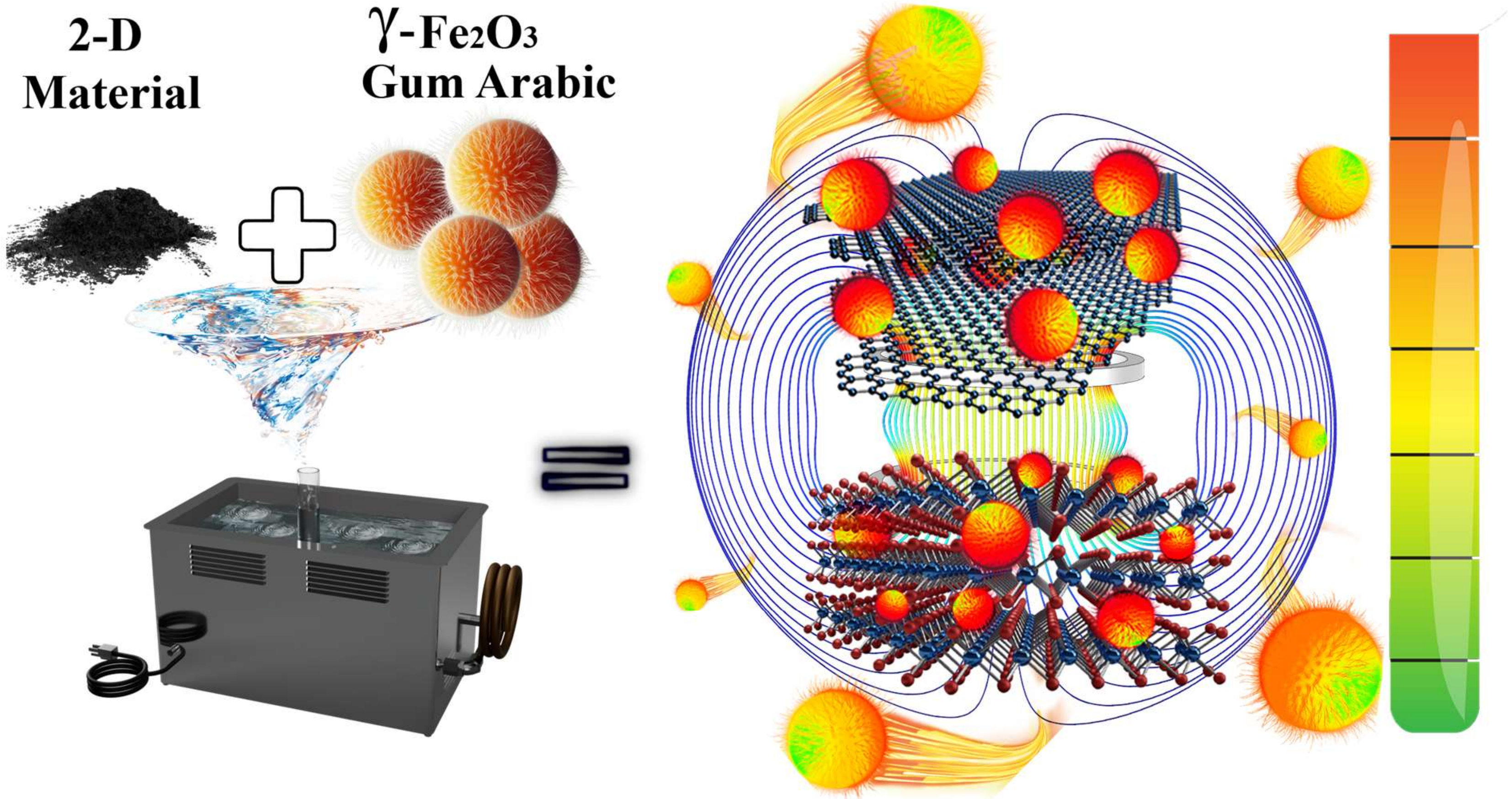
Progress in Surface Science 96 (2021) 100626/*Chem.Rev. 2018, 118, 6091−613*

vdWs materials: Deposition Techniques

Liquid Phase Exfoliated (LPE) dispersions is another alternative low-cost route for mass-scalable production of nanocomposites materials for HER



Application as an HER catalyst is ongoing, with promising early results.

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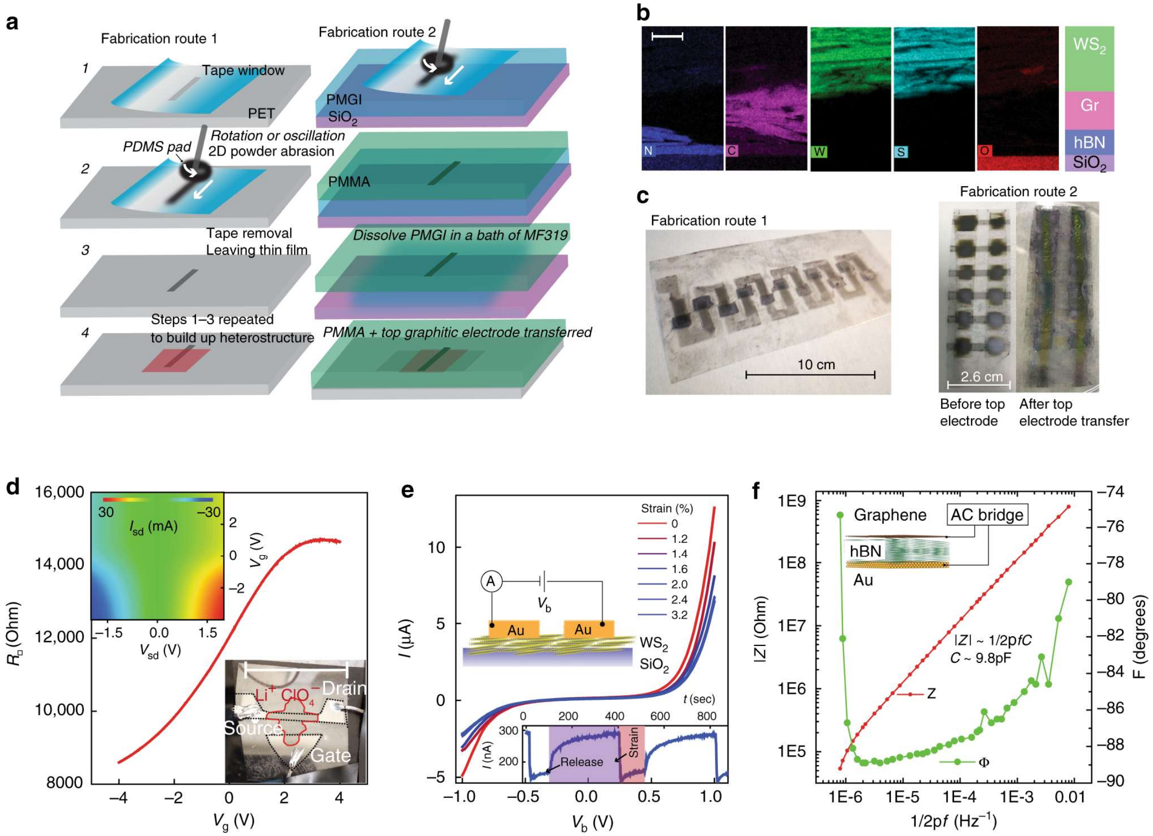
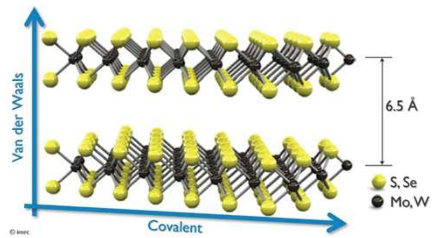
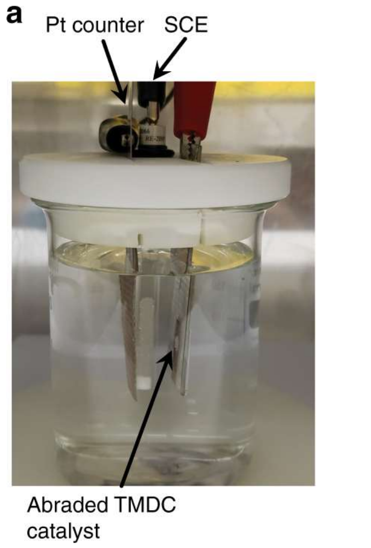
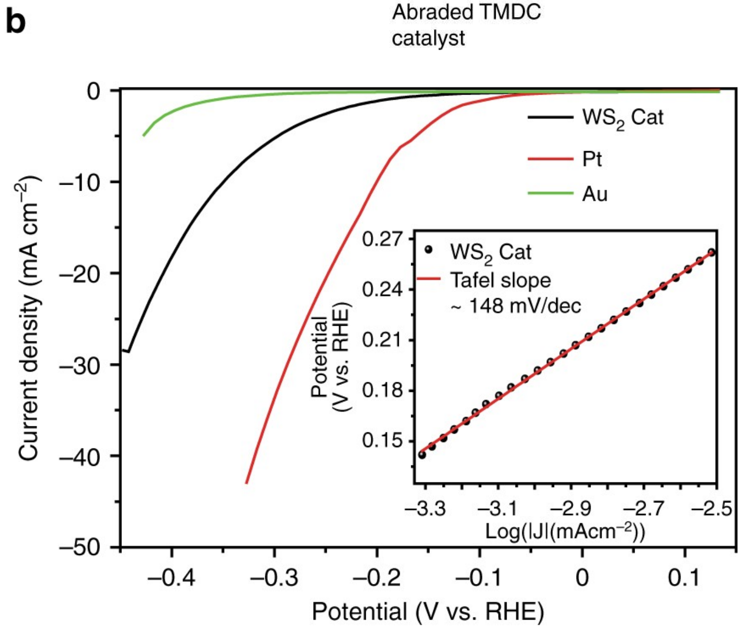
J.P. Caland... J.F. Felix, Materials & Design 255 (2025) 114176

vdWs materials: Deposition Techniques









Nutting, D., Felix, J.F., *et al.* Heterostructures formed through abraded van der Waals materials. *Nat. Commun.* **11**, 3047 (2020).

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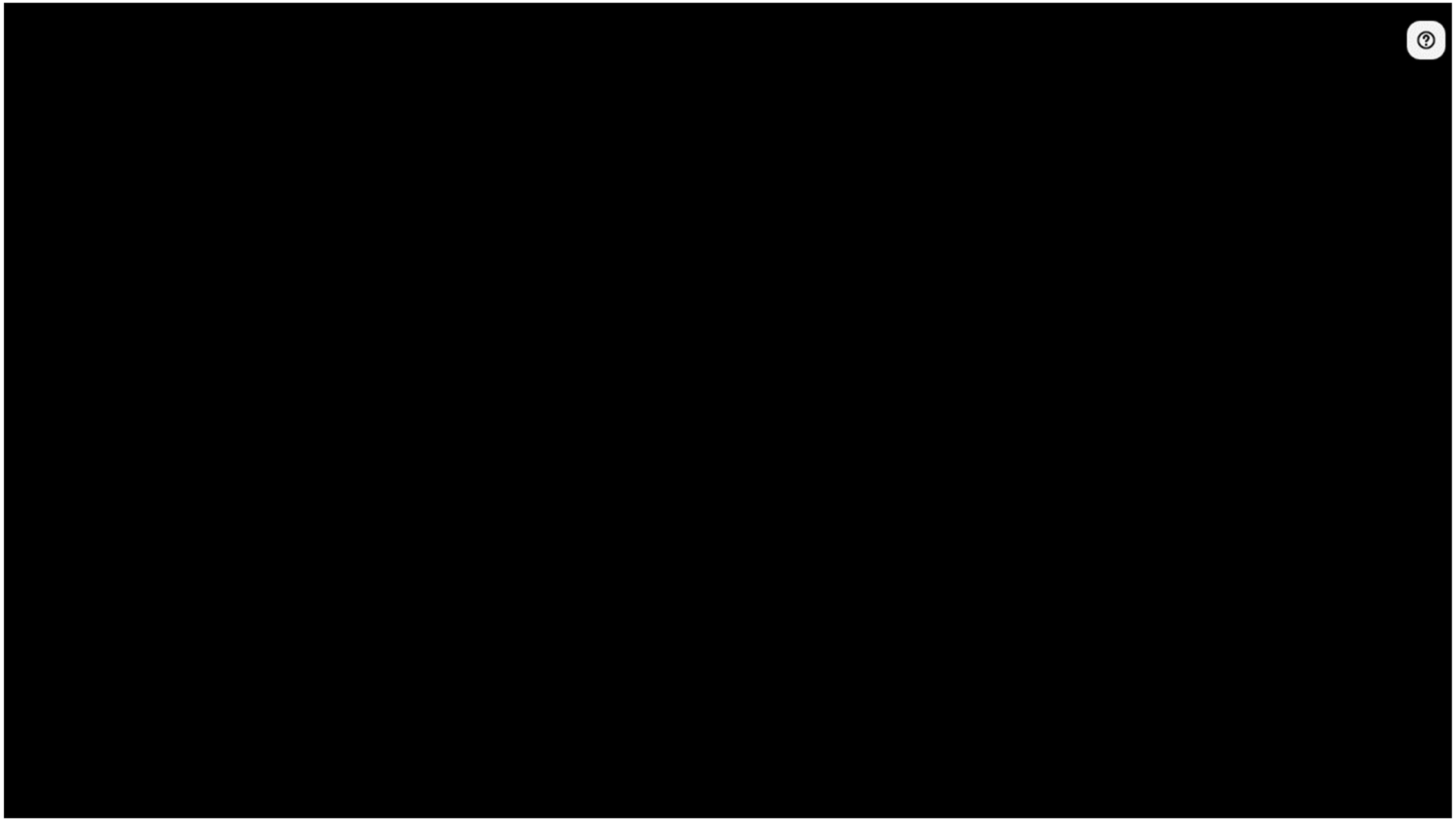
vdWs materials: Deposition Techniques

2D Materials Deposited by Automated Mechanical Exfoliation (AME)



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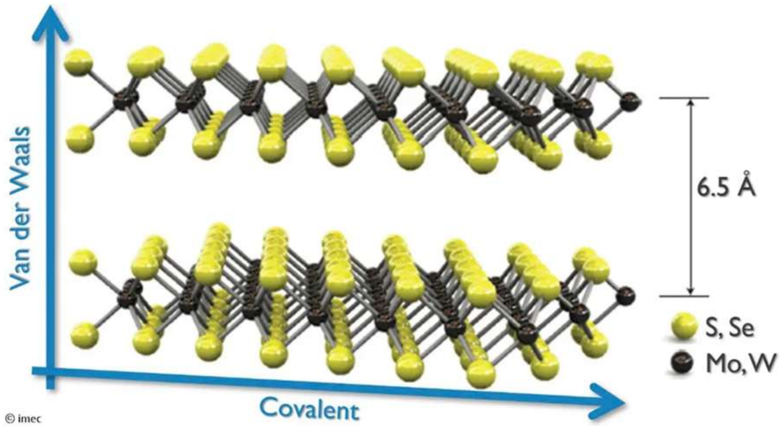
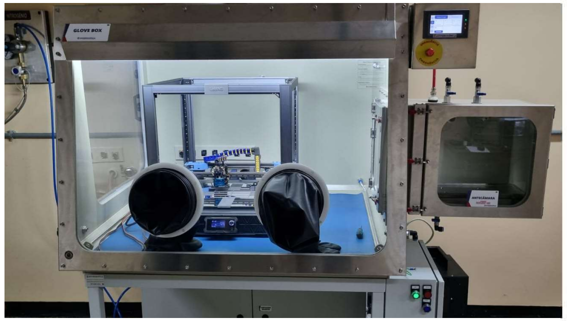
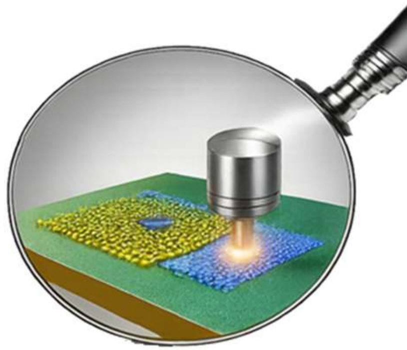
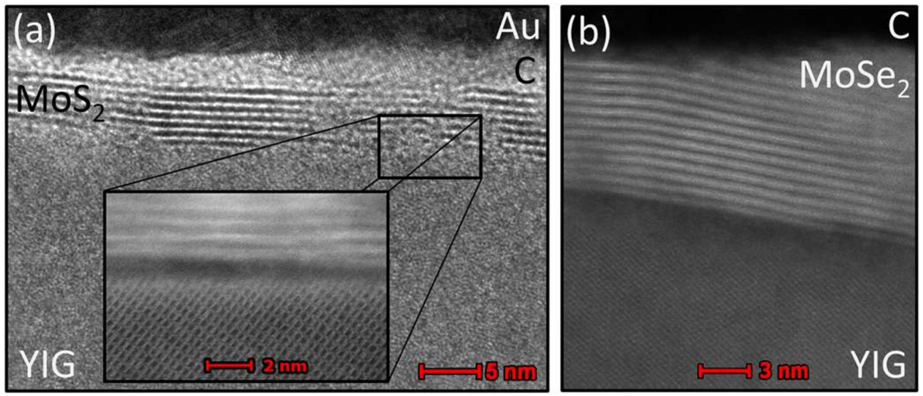
Automatic Mechanical Exfoliation (AME) of van der Waals Materials

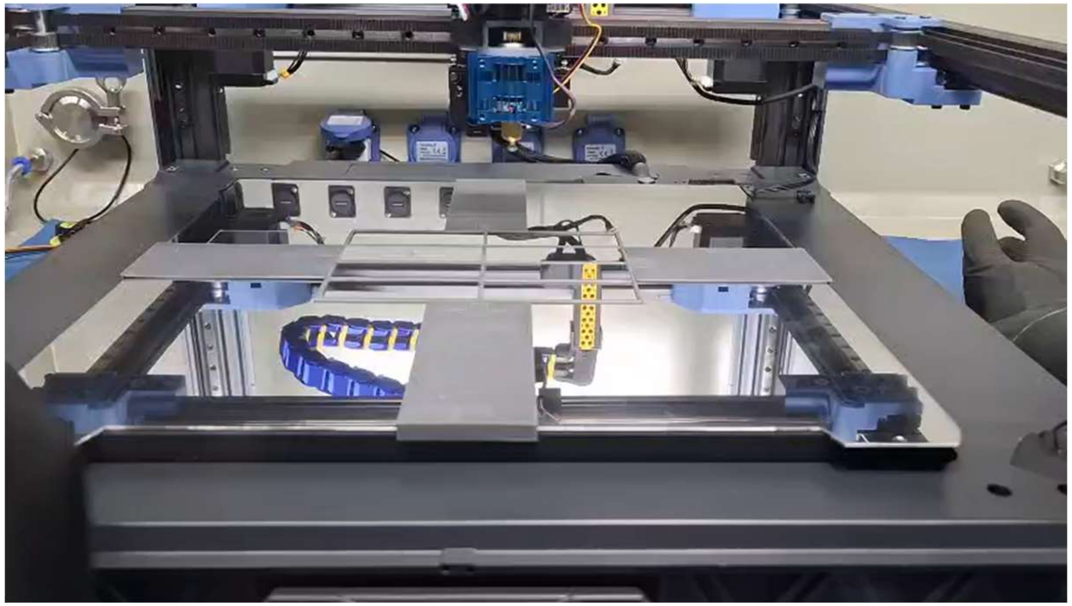








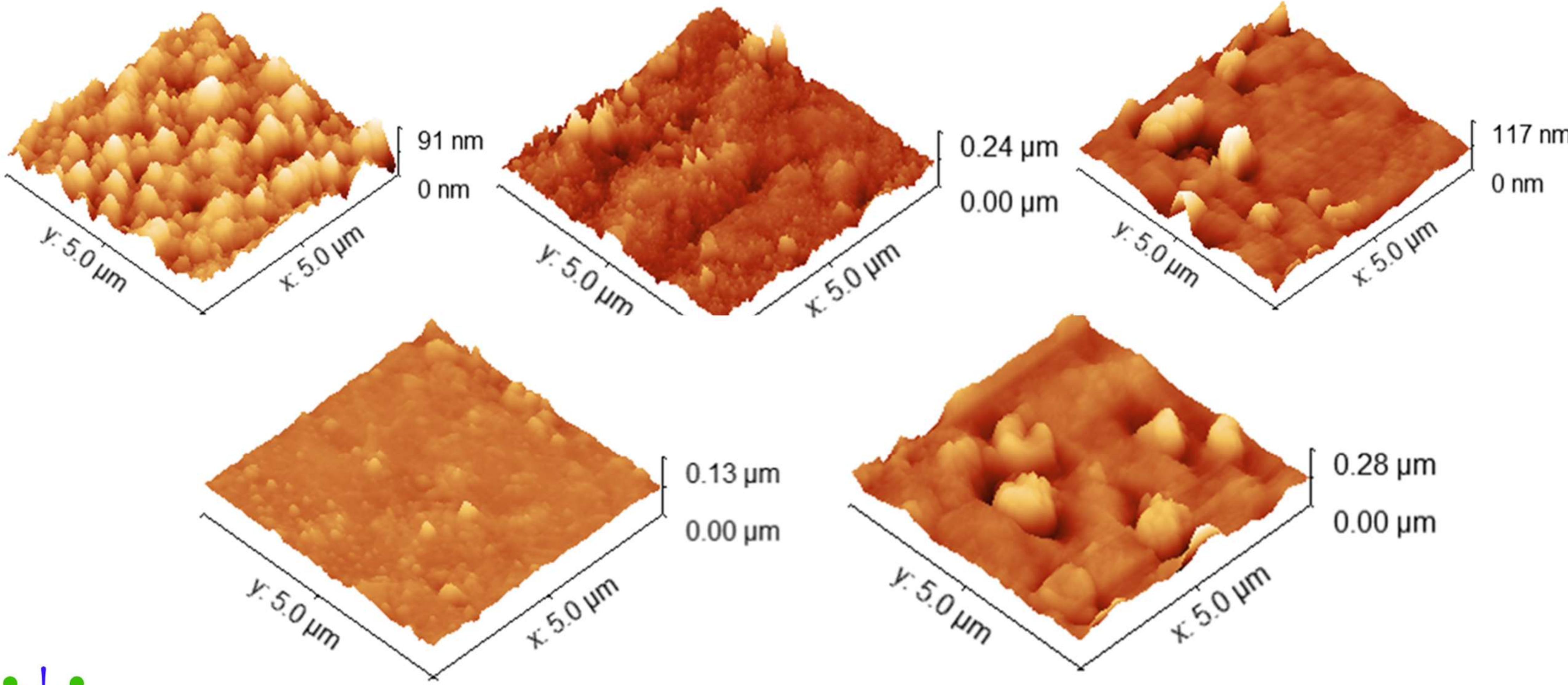
R.T. Victor... J.F. Felix Nanoscale Horiz., 2023, **8**, 1568-1576



Patent BR 1020240157060

Atomic Force Microscopy (AFM)

2D Materials Deposited by Automated Mechanical Exfoliation (AME)



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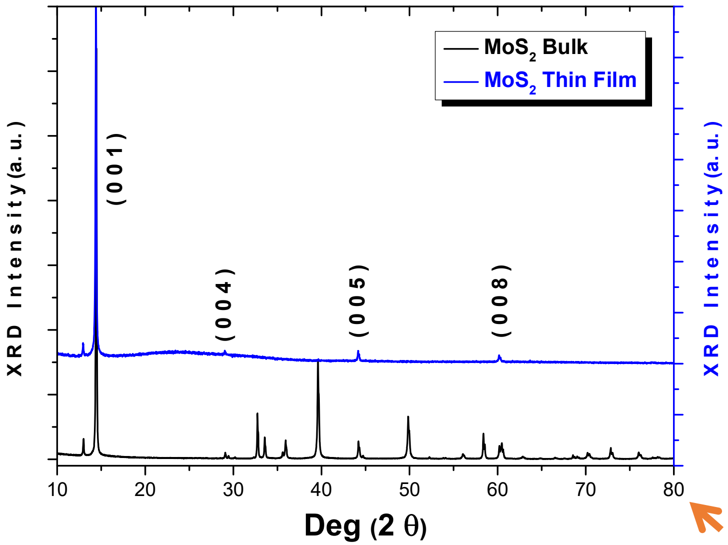
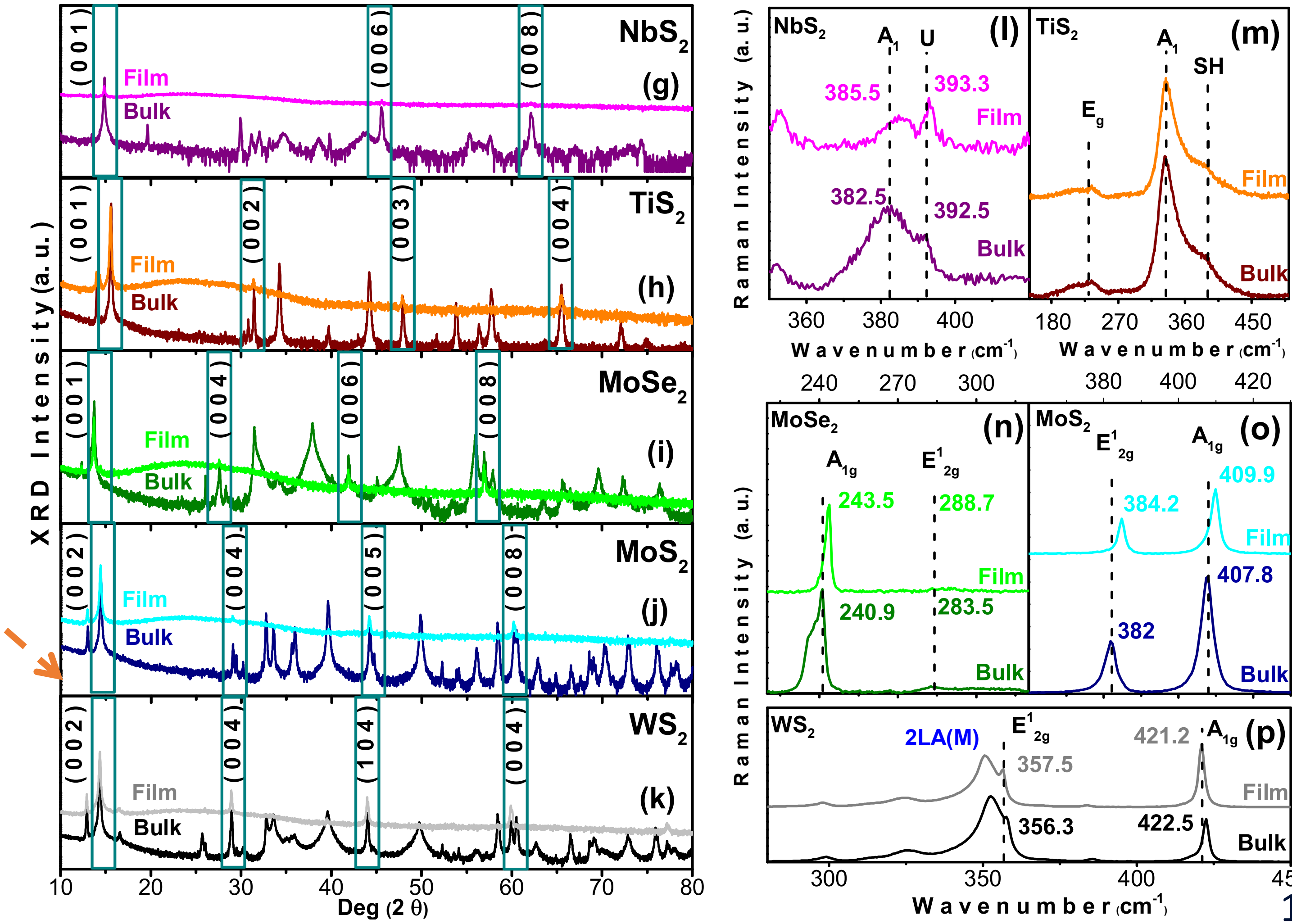
NbS_2, TiS_2, $MoSe_2$, MoS_2, and WS_2

X-Ray Diffraction and Raman Spectroscopy





Preferred (100) orientation — crystallites grow perpendicular to the substrate plane

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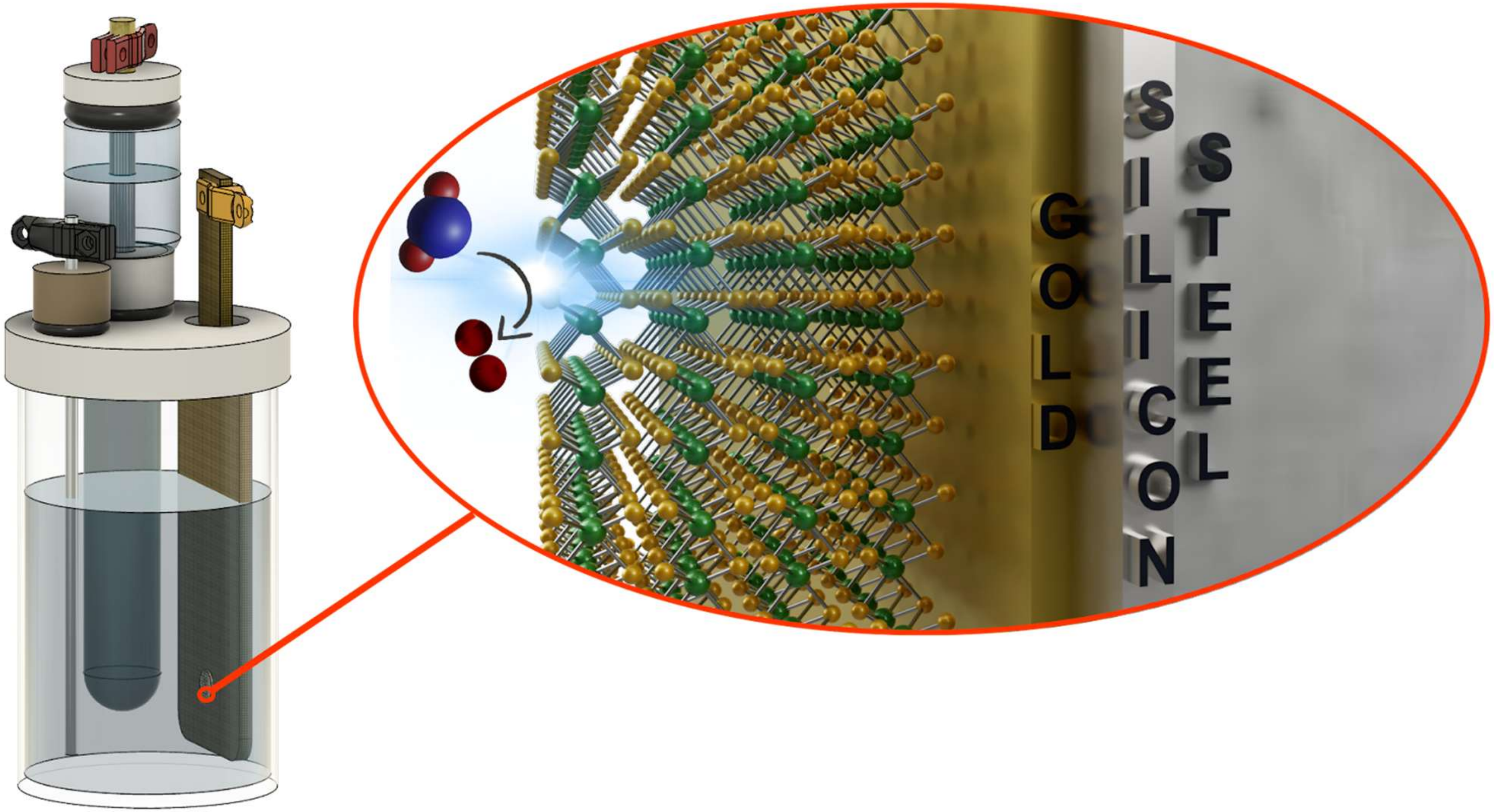
Mechanically Exfoliated TMDs thin films for Improved HER

2D Materials Deposited by Automated Mechanical Exfoliation (AME)



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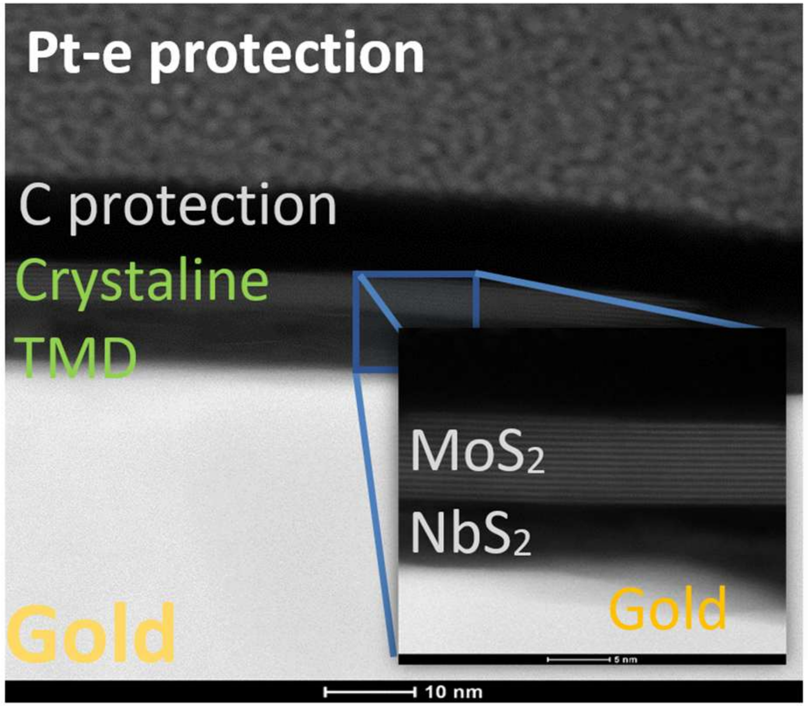
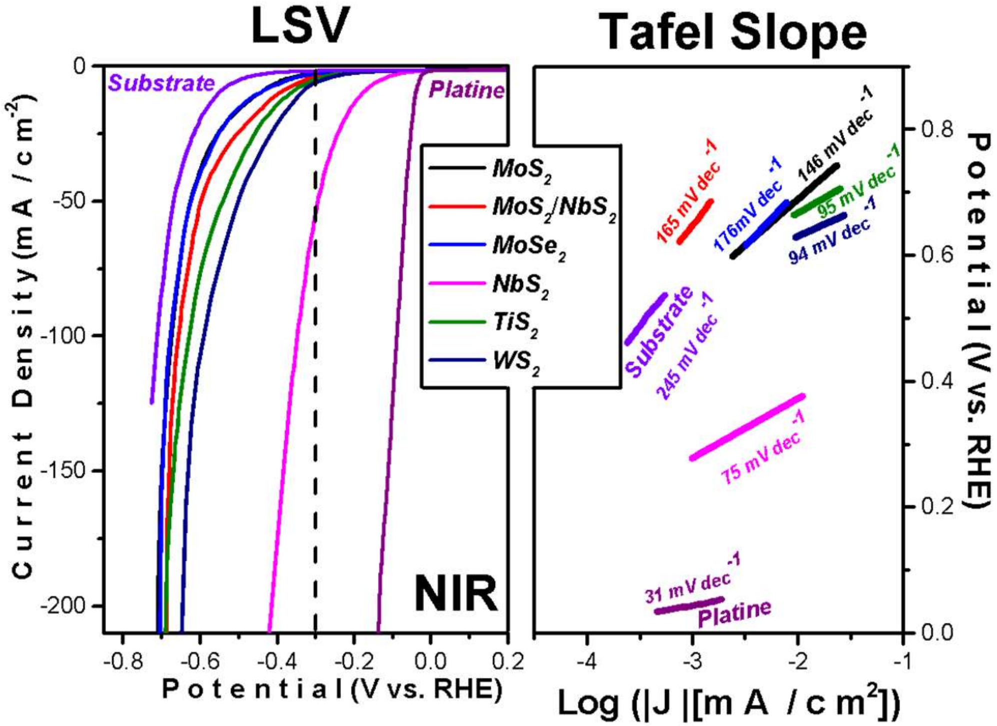
paper in submission process – figure designed by J. R. Marroquin

Mechanically Exfoliated TMDs thin films for Improved HER

2D Materials Deposited by Automated Mechanical Exfoliation (AME)

To effectively estimate the electrocatalytic materials, following key parameters are crucial :





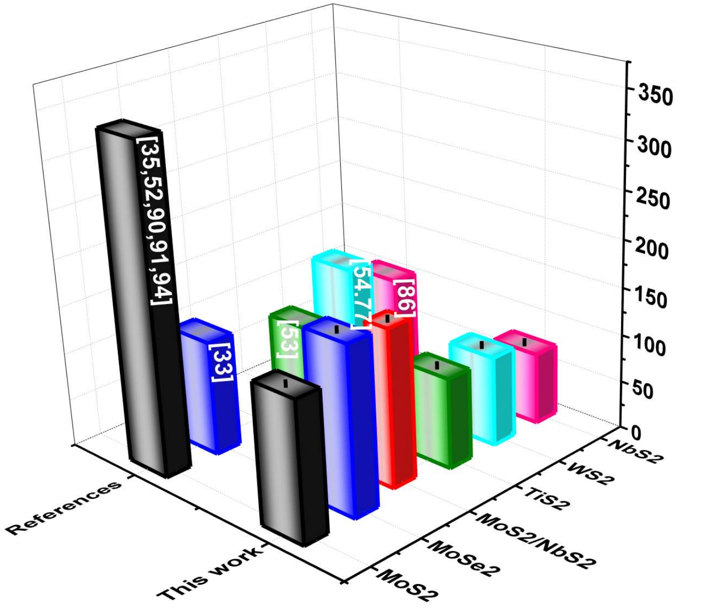
J. Marroquin et al. Chemical Engineering Journal Vol. 498, 2024, 155498

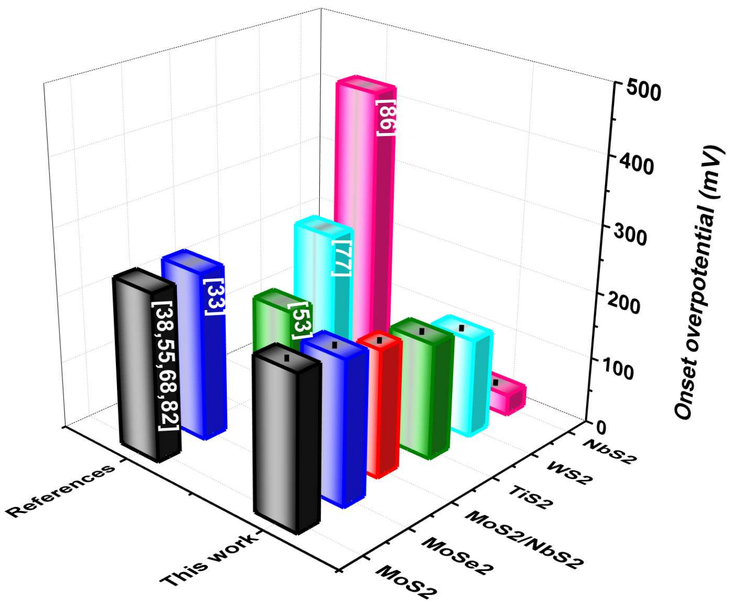
Platinum: high cost and scarcity hampers its wide application in large scale

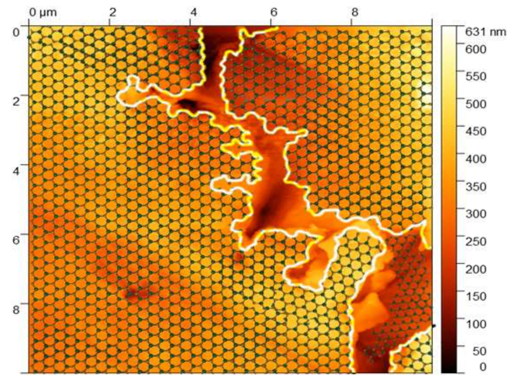
Mechanically Exfoliated TMDs thin films for Improved HER

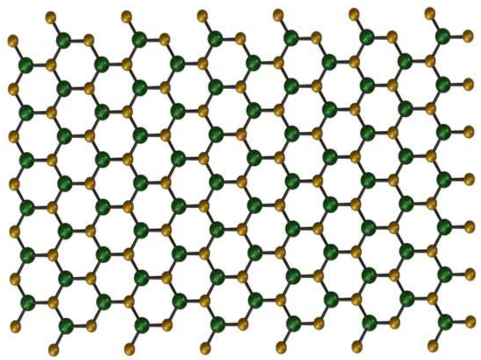
2D Materials Deposited by AME

To effectively estimate the electrocatalytic materials, following key parameters are crucial :









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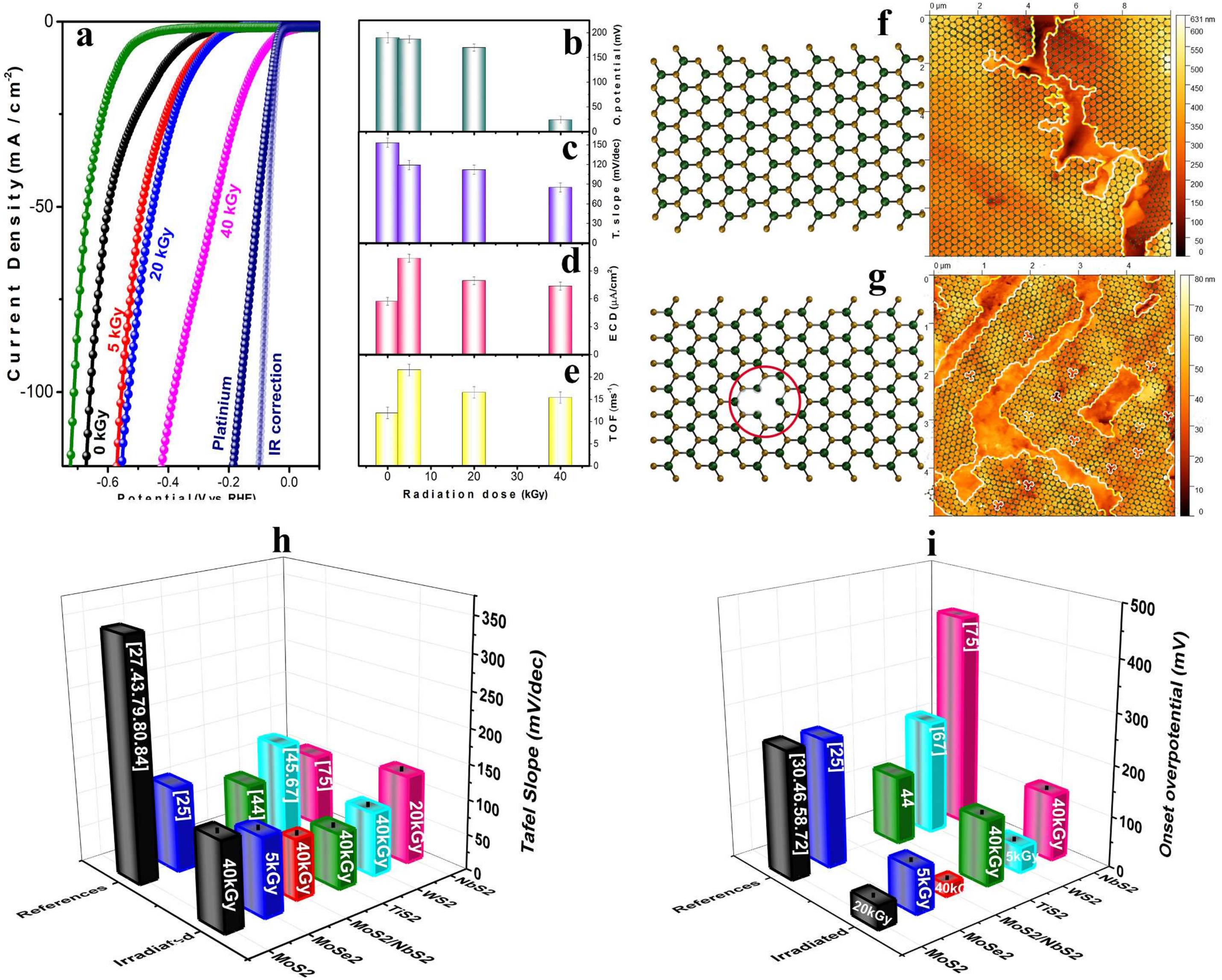
TMDs thin films for Improved HER after γ-rays



Chemical Engineering Journal 498 (2024) 155498

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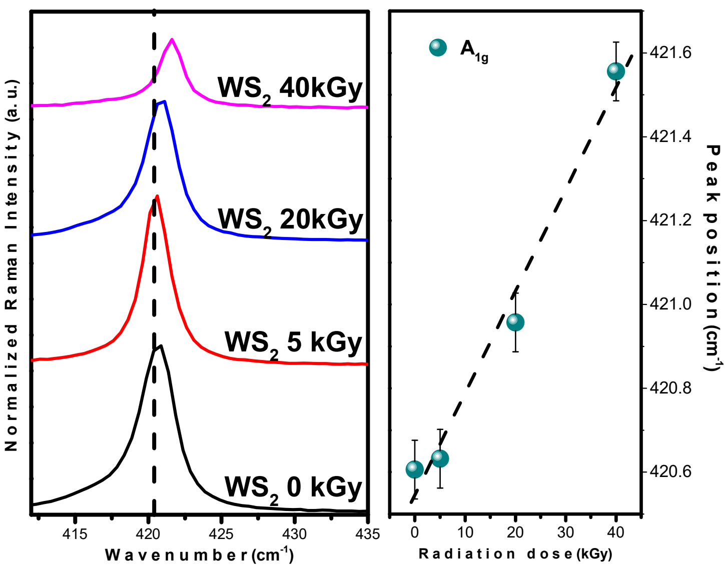
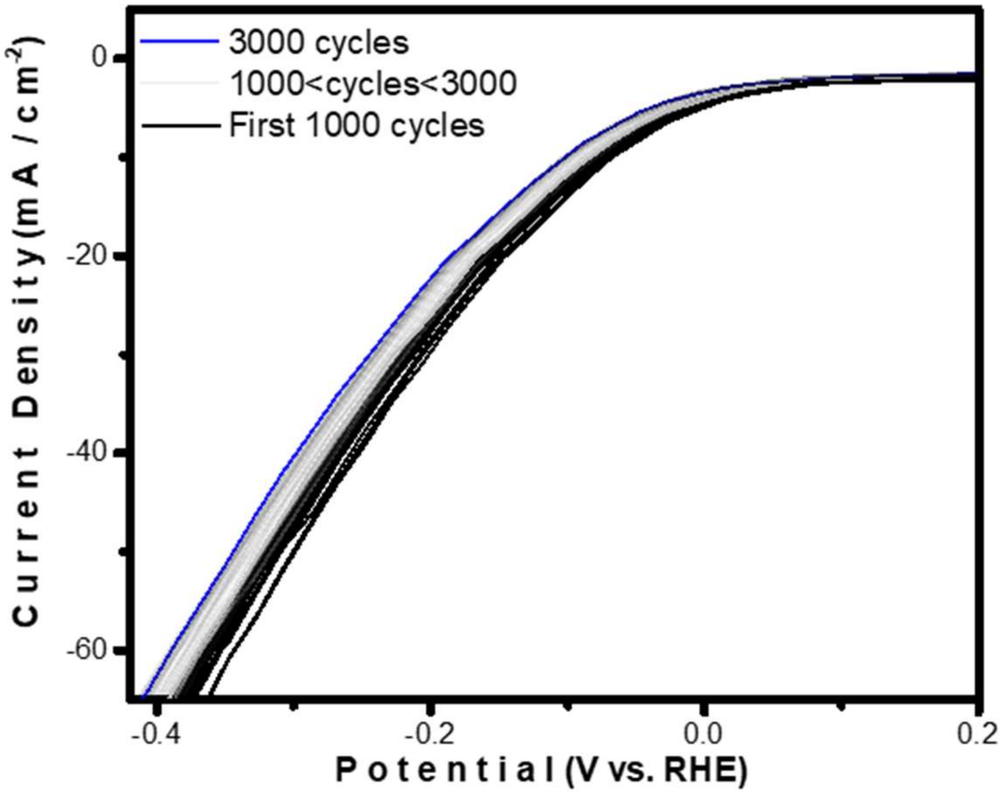
Mechanically Exfoliated TMDs thin films for Improved HER

2D Materials Deposited by Automated Mechanical Exfoliation (AME)

Stability: repetitive cyclic voltammetry (CV), running no less than 1000 cycles





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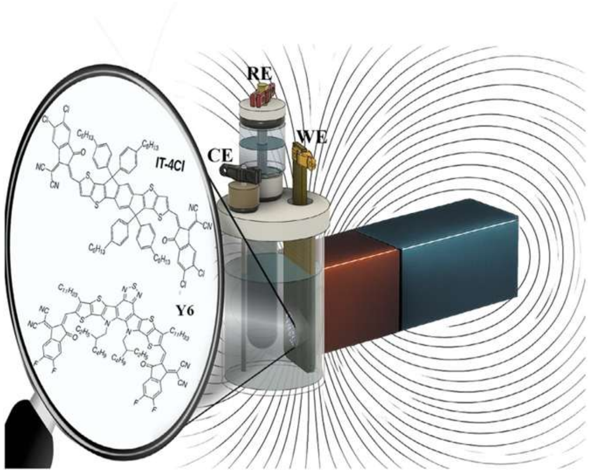
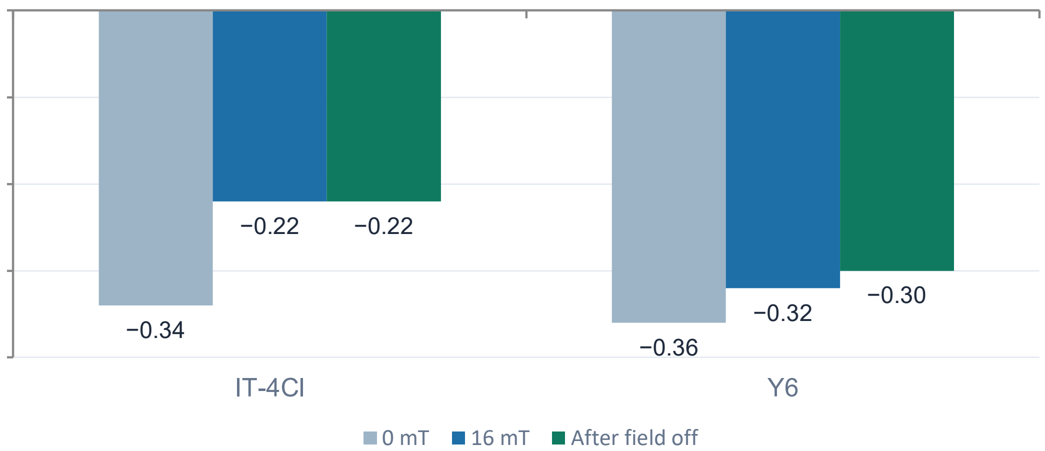
Chemical Engineering Journal Vol. 498, 2024, 155498

Magnetic fields boost HER in organic semiconductors

Weak magnetic fields (16–40 mT) applied during the hydrogen evolution reaction on non-fullerene acceptors (IT-4Cl, Y6) lower the onset potential and raise current density — and the gain persists after the field is removed.



Onset potential (V vs RHE)



16–40 mT
applied weak field

+0.12 V
onset shift, IT-4Cl (persistent)

240→200
Tafel slope, mV/dec (IT-4Cl)

≈3×
polaron density vs Y6 (EPR)

MHD · improves mass transport (Lorentz microconvection thins the diffusion layer)

MCE · modulates spin-dependent processes (singlet–triplet interconversion)

Souza, Koehler, Marroquin, Felix, et al., Advanced Materials Interfaces 2026, e70535

Recent projects approved by the group in the renewable energy field

Automated System for the Fabrication of 2D Materials for Green Hydrogen Production & Photovoltaic Devices

US$ 193,162.20 · funded by FAPDF

Period: 2025–2027

UnB Center of Excellence in CCUS: Solutions for Carbon Neutrality

R$ 14,749,544.16 (≈ US$ 2.9M) · funded by FINEP

Period: 2026–2029

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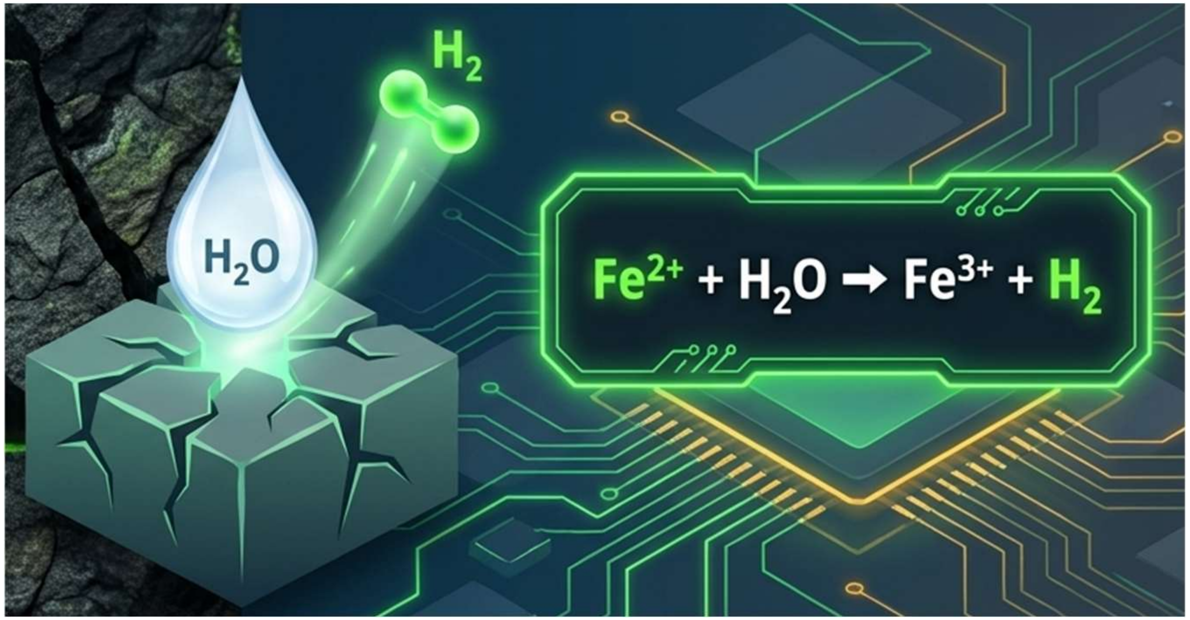
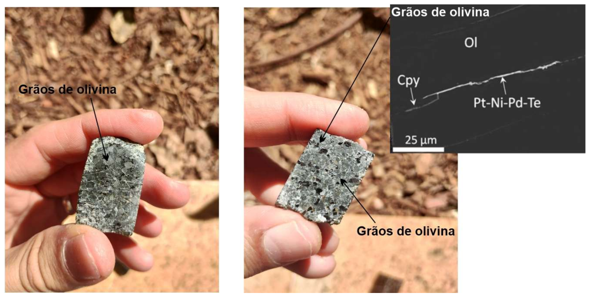
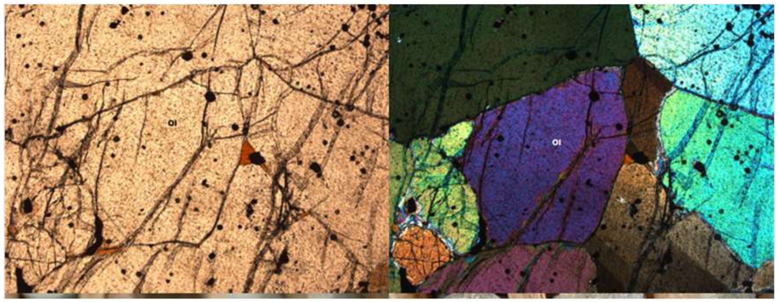
Natural (Geologic) Hydrogen

Natural generation of geologic hydrogen associated with water, rock interaction in ultramafic systems. We explore the serpentinization process to understand and induce H_2 release in natural systems.
The gas from the well has been directly powering the village of Bourakebougou with clean electricity for over a decade *[Int. J. Hydrog. Energy.,Volume 43, 2018,19315-19326].*



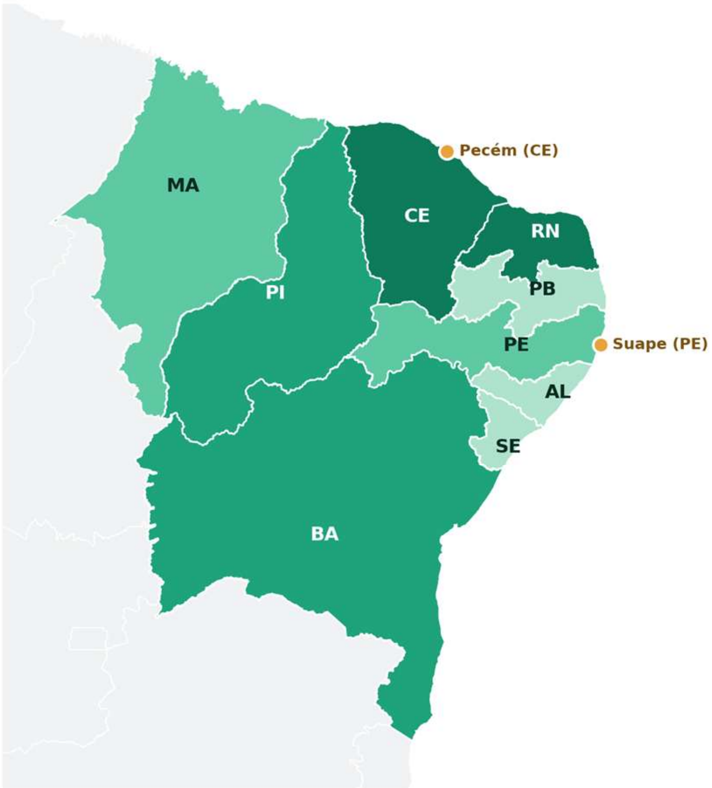
Applications: Assessment of prospective areas | Geochemical characterization of source systems





National & regional H_2 initiatives across Brazil

The Northeast: >85% of Brazil's wind power, 3,000+ sunshine hours/year, Atlantic ports facing Europe, and ~US$90 bn in announced investment.



A low-carbon hydrogen economy driven by both federal policy and state-led hubs — led by the Northeast, now spreading nationwide.

Federal government

- **National Hydrogen Program (PNH2)** — national strategy & roadmap.
- **Low-Carbon H_2 Law (14.948/2024)** — tax credits ≈ R$18.3 bn (2028–2032).
- **Federal funding** — BNDES & FINEP; planning by EPE/MME.

State (local) governments

- **Northeast leads** — Ceará (Pecém), RN (1st state H_2 law), Bahia, Pernambuco (Suape), Piauí, Maranhão.
- **Other states** — Rio G. do Sul, Rio de Janeiro (Açu), São Paulo, Espírito Santo, Minas Gerais.
- **Instruments** — state H_2 laws, MoUs, port clusters & incentives.

Public sources — federal programs & state governments, 2024–2026; figures vary by source and stage.

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Brazil's international H_2 cooperation

Bilateral partnerships

United Kingdom — Brazil–UK Hydrogen Hub · COP28 Joint Declaration, UNIDO secretariat

Germany — Brazil–Germany Energy Partnership · MME · MCTI · GIZ (18 H_2 studies, pilot plants)

Netherlands — co-chairs, International Hydrogen Trade Forum · SAF & maritime fuels

Multilateral & financing

World Bank & BNDES — financing across the low-carbon H_2 value chain (COP28)

Climate Investment Funds (CIF) — Industry Decarbonization window

COP28 declarations — mutual recognition of H_2 certification; public–private H_2 trade

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Source: Brazil – Ministry of Mines and Energy (MME) · National Hydrogen Program (PNH2), International Cooperation (2023–2025).

Open to collaboration

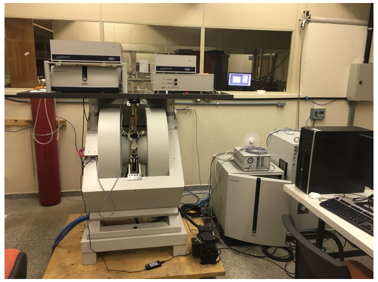
Founded over 10 years ago at the University of Brasília and led by Jorlandio F. Felix, LabINS warmly welcomes collaboration, exchange of ideas, and visits to our laboratories. Partnerships grow through individual cooperation calls and encounters at conferences and workshops.

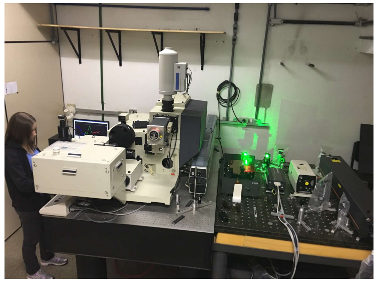
Ways to collaborate

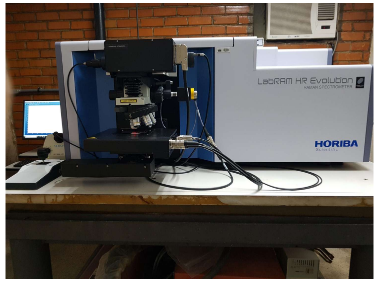
- Joint research through individual cooperation calls
- Research visits and short stays at LabINS
- Exchange of students, samples and ideas
- Meeting at conferences, workshops and schools

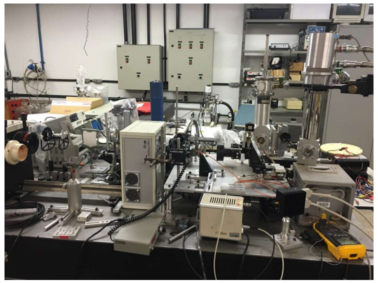
LabINS — what we offer

- AME platform: automated mechanical exfoliation of 2D vdW materials (patented)
- Liquid-phase exfoliation and functional inks
- SQUID magnetometry · Raman · XRD · AFM- SEM- HER infrastructure, etc.
- 2D-flake / PDMS composites and catalysis (HER)









Final Considerations

➢ Key results

- Patented AME platform — scalable, solvent-free 2D TMD thin films
- Films of MoS_2, WS_2, NbS_2, TiS_2 and $MoSe_2$ via this unconventional process
- WS_2 & MoS_2: onset potential lower than comparable literature values
- HER tunable by γ-irradiation and boosted by magnetic fields

➢ Perspectives

- Scale-up & device integration of AME films
- Defect & field engineering for new catalysts
- Natural (geologic) H_2 & renewable-energy projects in Brazil

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Acknowledgements

THANK YOU FOR YOUR ATTENTION!

CNPq

CAPES

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fapdf

IF

Ministry of Science, Technology and Innovation

BRAZILIAN GOVERNMENT BRASIL

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Catalyzing Change, Layer-by-Layer

Finep
INOVAÇÃO E PESQUISA