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IIT Guwahati MXene Catalyst: Hydrogen Fuel and Solar Desalination

18 March 2026

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18 March 2026 · 4 min read ·

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WHY IN NEWS

Researchers at IIT Guwahati, led by Prof. P.K. Giri, published a breakthrough in Advanced Functional Materials: an MXene-based material that simultaneously enables hydrogen fuel production through water electrolysis and solar-powered seawater desalination — two of the most critical clean energy and water security challenges.

WHAT IS MXENE?

MXenes are a family of **two-dimensional (2D) transition metal carbides, nitrides, or carbonitrides** first discovered in 2011 at Drexel University, USA. They are derived by selectively etching (removing) layers from a parent **MAX phase** material.

WHY MXENES MATTER

Exceptionally high electrical conductivity (comparable to metals)

Large surface area — provides more active sites for chemical reactions

Hydrophilic surface — bonds well with water molecules; critical for both electrolysis and desalination

Tunable chemistry — properties can be engineered by varying the metal and surface functional groups

Applications: energy storage (supercapacitors), sensors, electromagnetic shielding, catalysis

IIT GUWAHATI'S INNOVATION

The team engineered MXene into **ultra-thin ribbon-like nanostructures** and introduced **ruthenium (Ru) atoms** into **oxygen-deficient sites** within the MXene lattice. This creates highly active catalytic centres that dramatically lower the energy barrier for the **Hydrogen Evolution Reaction (HER)**.

HYDROGEN FUEL PRODUCTION VIA WATER ELECTROLYSIS

Water electrolysis splits water (H_2O) into hydrogen (H_2) and oxygen (O_2) using electricity:

$$2H_2O \rightarrow 2H_2 + O_2$$

KEY METRIC — OVERPOTENTIAL

The **minimum thermodynamic voltage** needed to split water is **1.23 V**. In practice, catalysts require extra voltage ("overpotential") to overcome kinetic barriers. **Lower overpotential = more efficient catalyst.**

Catalyst	HER Overpotential
Platinum (Pt/C) — gold standard	~20–50 mV
IIT Guwahati MXene-Ru	**12 mV**

The IIT Guwahati material **outperforms platinum** — the current benchmark — at a fraction of the cost, since ruthenium is far cheaper than platinum.

WHY HYDROGEN FUEL?

- Burns to produce **only water vapour** — zero CO_2 emissions
- Can be used in fuel cells for electricity, or directly combusted in industrial processes
- Critical for decarbonising sectors like steelmaking, shipping, and heavy transport
- India's **National Green Hydrogen Mission** (launched January 2023) targets 5 million tonnes/year of green hydrogen by 2030

SOLAR DESALINATION VIA 3D JANUS EVAPORATOR

The same MXene material was integrated into a **3D Janus evaporator** for **solar-driven seawater desalination**.

WHAT IS A JANUS EVAPORATOR?

A **Janus structure** has **asymmetric wettability** — one side is hydrophilic (attracts water) and the other is hydrophobic (repels water). This directionality:

- Drives water upward toward the surface through capillary action

Concentrates solar heat at the water-air interface

Prevents salt accumulation that clogs conventional evaporators

PERFORMANCE

Evaporation rate: ~3.2 kg/m²/h under one sun (1 kW/m² solar irradiance)

Operated continuously for **5 days** without salt fouling or performance degradation

Purified water meets **WHO and BIS international drinking water standards**

GLOBAL CONTEXT

~2.2 billion people lack safe drinking water (WHO 2022)

Coastal and island communities rely on desalination, but conventional reverse osmosis is energy-intensive

Solar desalination using photothermal materials (like MXene) requires **no electricity** — powered entirely by sunlight

SIGNIFICANCE FOR INDIA

WATER SECURITY

India faces acute water stress. The **National Water Mission** (one of 8 National Action Plans on Climate Change) and **Jal Jeevan Mission** both recognise desalination as part of the long-term water security toolkit, especially for coastal Tamil Nadu, Gujarat, Andhra Pradesh, and island territories.

ENERGY SECURITY

India imports ~**87-89%** of its crude oil (FY 2025-26 data: ~88.6% import dependence). Green hydrogen as a substitute can reduce this dependence. The National Green Hydrogen Mission and the **Hydrogen Valley Programme** are active policy frameworks.

INDIGENOUS R&D

This research represents **Atmanirbhar Bharat** in deep-technology: an Indian institution developing catalysts that outperform imported platinum standards, with implications for scaling up domestic hydrogen and desalination industries.

UPSC RELEVANCE

MXene definition, Janus evaporator, IIT Guwahati, HER overpotential, National Green Hydrogen Mission.

MAINS GS-3:

Clean energy technology; water security; India's hydrogen mission; role of IITs in innovation.

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IIT GUWAHATI MXENE RESEARCH:

Lead researcher: **Prof. P.K. Giri**, IIT Guwahati

Published in: **Advanced Functional Materials** (peer-reviewed international journal)

Material: **MXene** (2D transition metal carbide/nitride) + **Ruthenium (Ru)** atoms

Structure: Ultra-thin ribbon-like nanostructures

HER overpotential: **12 mV** (better than Pt/C at ~20–50 mV)

Solar desalination rate: **~3.2 kg/m²/h**

Continuous operation: **5 days** without salt fouling

Water quality: Meets **WHO/BIS** drinking water standards

KEY TECHNICAL TERMS:

MXene: 2D material, first discovered 2011 at Drexel University, USA

Overpotential: Extra voltage needed above 1.23 V thermodynamic minimum

Janus evaporator: Asymmetric wettability structure for solar evaporation

HER: Hydrogen Evolution Reaction ($H_2O \rightarrow H_2$)

Ruthenium (Ru): Platinum-group metal, cheaper than Pt, catalytically active

POLICY FRAMEWORKS:

National Green Hydrogen Mission: Launched January 2023; target 5 MT/year by 2030; outlay Rs. 19,744 crore

National Water Mission: One of 8 NAPCCs; addresses water conservation and supply

Jal Jeevan Mission: Rural piped water supply to every household; original target 2024, **extended to 2028** (Union Budget 2025-26)

Hydrogen Valley Programme: Pilot zones for hydrogen economy development

OTHER RELEVANT FACTS:

India imports ~87-89% of crude oil (FY26: ~88.6%); green hydrogen can reduce fossil fuel dependence

2.2 billion people worldwide lack safe drinking water (WHO 2022)

Reverse osmosis (conventional desalination) consumes ~3–10 kWh per cubic metre of water

Solar desalination with MXene requires zero external electricity — sun-powered only

IIT Guwahati: Established **1994** by an Act of Parliament; academic programme commenced **1995**; located on the north bank of the Brahmaputra River, Assam

Sources: Advanced Functional Materials, IIT Guwahati

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