भारतीयप्रौद्योगिकीसंस्थान (भारतीयखनिविद्यापीठ), धनबाद
Indian Institute of Technology (Indian School of Mines), Dhanbad

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PIONEERING RESEARCH

IIT (ISM) Dhanbad Electronics Engineering Department Showcases Breakthrough Research in Next-Gen Memory and Energy Devices

The Department of Electronics Engineering at IIT (ISM) Dhanbad continues to make significant strides in advanced memory technologies and flexible energy storage systems, positioning itself at the forefront of neuromorphic computing and wearable electronics research. The department's recent contributions include four high-impact publications in international journals, highlighting innovations in **memristive devices** and **flexible supercapacitors**.

1. Yttrium Oxide-Based Memristors: A Comprehensive Review

In a systematic review titled *"Progress, Perspectives, and Future Outlook of Yttrium Oxide-Based Memristive Devices for Data Storage, Multibit Programming, and Neuromorphic Computing"*, researchers Aarti Dahiya, Sanjay Kumar*, Shalu Rani, and Shaibal Mukherjee* explore the unique potential of Y_2O_3 memristors. Owing to its high bandgap (5.7 eV), moderate dielectric constant (14–18), and lower work function (~2 eV), Y_2O_3 enables forming-free, low-temperature switching with excellent Schottky contact.
The review, published in *ACS Applied Electronic Materials* (Impact Factor: 4.7), lays out pathways for optimizing memristor performance through structural engineering, doping, annealing, and optical/ion beam stimuli. The devices exhibit promise for data storage, neuromorphic computing, synaptic learning, and flexible memory applications.
[DOI: https://doi.org/10.1021/acsaelm.5c01025]

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2. TiN-Engineered Y_2O_3 Memristor: High Endurance for Pattern Recognition

Addressing dimensional limitations and performance variability in oxide-based memristors, the research team led by Dr. Sanjay Kumar and Dr. Shalu Rani demonstrated an advanced Y_2O_3 memristor using TiN electrodes and device scaling. The device, fabricated using RF sputtering, achieved:

- **Endurance:** 50,000 cycles
- **Retention:** 10^6 seconds
- **ON/OFF ratio:** 10^4
- **Pattern recognition accuracy:** 88.2% using ANN
- **Cycle-to-cycle variation:** 4.95%, device-to-device variation: 11.39%

Published in *IEEE Transactions on Materials for Electron Devices*, the work establishes this memristor as a viable candidate for neuromorphic and edge AI systems.
[DOI: 10.1109/TMAT.2025.3579714]

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3. Flexible Yarn Supercapacitors for Wearable Electronics

In the energy storage domain, researchers led by Dr. Shalu Rani and Dr. Sanjay Kumar, in collaboration with international experts, have developed **twistable $ZnMn_2O_4$-based yarn supercapacitors**. Using electrodeposition on carbon yarn and PVA-H_3PO_4 gel electrolyte, the device demonstrated:

- **Areal capacitance:** 87.6 mF/cm²
- **Cycle life:** 92% capacitance retention after 10,000 cycles

- **Practical performance:** Stable operation under bending/twisting and successful LED illumination

Accepted in *ACS Applied Materials & Interfaces* (Impact Factor: 8.2), this innovation is a step forward in sustainable, wearable energy solutions.

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4. Wafer-Scale HfO_2/Ta_2O_5 Memristors via ALD for Crossbar Arrays

In another notable work, Dr. Sanjay Kumar and team presented a novel **ALD-grown HfO_2/Ta_2O_5 bilayer memristor** with significantly improved uniformity and lower switching voltages—key for high-density neuromorphic architectures. Key results include:

- **Forming voltage:** +5.5 V
- **Switching voltages:** VSET = +3.75 V, VRESET = -4.01 V
- **Cycle-to-cycle variability (CV):** as low as 1.70%
- **Mean Absolute Error (MAE):** Reduced by up to 45% across devices

The paper appears in *Frontiers in Nanotechnology* (Impact Factor: 3.8).
[DOI: https://doi.org/10.3389/fnano.2025.1621554]

Driving Innovation with ROAM and SYNERGY Labs

These research outcomes are the result of intensive R&D led by the **ROAM Group** and **SYNERGY Lab** in the Department of Electronics Engineering. The department continues to foster global collaborations and interdisciplinary integration in materials science, device physics, and AI hardware.

Rajni Singh
Dean (Corporate Communications)