SHIV NADAR
INSTITUTION OF EMINENCE DEEMED TO BE
UNIVERSITY
DELHI NCR

SUSTAINABILITY INITIATIVES

IMPACT STORY 1

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Image: Anant Bhagat, Chemical Engineering 2023, Shiv Nadar University

Overview

With a broad remit around creating and disseminating knowledge, universities are powerful drivers of local, regional, and global innovation, economic development, and societal well-being. By nurturing the next generation of skilled citizens, universities play a vital role in preparing future leaders. When knowledge and ideas move from university laboratories and lecture rooms into society through partnerships, the knowledge and ideas begin to make an impact.

At Shiv Nadar University, we bring you some of these impact stories through our sustainability initiatives. The stories feature our faculty, their research, and students creating a difference and contributing to UN Sustainable Development Goals (SDGs).

Today, we bring you an exciting conversation with Dr. Harpreet Singh Arora.

> He has been featured in Stanford University's top 2% of scientists list as one of the top 2% most-cited scientists in various disciplines.

You have been in the top 2% of Stanford's list for the last few years. What inspires your work and your motivation in research?

The key motivation for my research is to contribute to addressing the pressing global challenges and provide a low-cost, efficient, and sustainable solution. The current focus areas of my research include clean energy (hydrogen generation) and energy storage devices, such as supercapacitors and batteries. These research areas are inspired by the urgent need to reduce dependence on fossil fuels, address rising environmental concerns, and achieve net-zero targets.

Dr. Harpreet Singh Arora

Dr. Harpreet Singh Arora, Professor and head of the Department of Mechanical Engineering at Shiv Nadar University, is working on cutting-edge research in energy studies. He has been featured in Stanford University's Top 2% of Scientists list as one of the top 2% most-cited scientists in various disciplines.

Dr. Arora's research interests include using different surface engineering approaches, including friction stir processing and advanced materials for addressing material degradation, energy storage, and the development of supercapacitors.

One of the key frameworks to check global progress towards sustainability is the UN Sustainable Development Goals. SGD 7 is about access to clean and affordable energy and, at the same time, addresses the growing energy demand and urgent need to mitigate climate change. How does your work contribute to sustainability, and what are some of the key elements of your research in 2023 in sustainability?

Our vision for a sustainable future needs an urgent transition from fossil fuel-based energy sources to renewable and non-polluting options. Solar and wind are currently the most exploitable renewable energy sources. However, the temporal and spatial intermittencies of solar and wind energy necessitate storage of the generated energy, wherein electrochemical energy storage devices such as supercapacitors play a vital role. Despite significant advancements, the performance of supercapacitor electrodes, particularly their specific capacitance and energy density, is lacking and needs further improvement. Thus, one of my group's key research areas is developing high-performance supercapacitor devices.

In addition, using non-polluting energy carriers such as green hydrogen is becoming extremely popular to address the rising energy and environmental concerns. Water electrolysis is one of the key technologies for the generation of green hydrogen. However, one major bottleneck in the large-scale utilization of water electrolysis is the high cost and scarcity of noble metals-based catalysts. Thus, a huge interest is developing low-cost and efficient catalysts for electrochemical water-splitting applications. My group is actively working in this domain, developing a low-cost, highly efficient, and scalable technology that can address the current challenge of large-scale green hydrogen production.

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How have you been able to connect and include sustainability in your teaching?

I have developed a course on *"Fundamentals of Hydrogen Fuel Cell Technology"* for undergraduate students. The course addresses the need to understand the hydrogen economy and its importance as an alternative energy source. It covers the spectrum from generation to utilization of green hydrogen in fuel cells. The course begins with the current technology to produce green hydrogen and the fundamentals of electrochemistry. It then progresses into fuel-cell technology and its fundamental understanding. Thus, it provides a comprehensive overview of the current fuel-cell technology, challenges to address, and pathways to develop a sustainable ecosystem.

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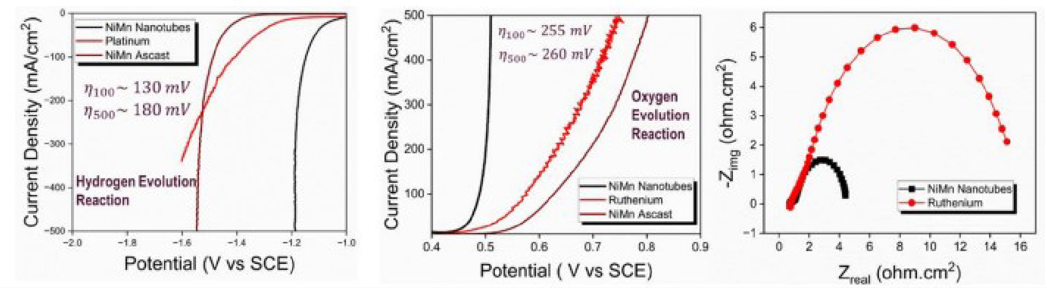
What are some of your students' key research projects?

Development of efficient catalysts for green hydrogen generation through electrochemical water splitting

A Ph.D. student is working to develop efficient electrocatalysts for hydrogen generation through overall water splitting, considered one of the cleanest and most eco-friendly techniques for hydrogen production. This is a novel processing technique that uses a short burst of physical deformation along with selective de-alloying (SD) deployed to synthesize unique nano-tubular NiMn-oxy (hydroxide) structures (NTSD). The project demonstrates an outstanding electrochemical performance of bi-functional nano-tubular NiMn-(oxy) hydroxide for overall water splitting(figure 1). It is a unique perspective for developing highly effective catalysts using a top-down approach, which can be extended to a wide range of material systems.



High-performance supercapacitors for energy storage applications

Two students are pursuing their Ph.D. to develop high-performance energy storage devices. Their work focuses on synthesizing energy-dense devices without compromising power density and life cycle. The research involves an in-situ synthesis of a nano-textured active layer over the current collector through techniques that can directly be used for energy storage and catalysis applications.

What are some of your partnerships and collaborations with Industry and Academia?

We have collaborated with specific research groups in institutions, such as North Carolina State University, North Carolina; University of North Texas, USA; and the University of Petroleum and Energy Studies, Dehradun.

The purpose of these collaborations is to carry out advanced characterization of materials. My group at Shiv Nadar synthesizes these materials for various energy storage and catalysis applications. The collaborators help perform advanced characterization, including transmission electron microscopy (TEM), atom-probe tomography (APT), and electron energy loss spectroscopy (EELS), in their highly specialized and advanced research facilities for better scientific understanding.

In industries, we have collaborated with Nansol Energy, a Hyderabad-based Indian start-up, to develop low-cost, high-performance anion-exchange membrane-based electrolyzers for green hydrogen generation.

Patent (Published)

Nano-moulding of Metals and Alloys and Process Thereof,
Patent Application Number: 202111048897

We have published a patent about a novel technique to develop nano-textured metallic surfaces through nano-moulding. Such nano-textured metallic surfaces find immense application in green hydrogen generation through water splitting and energy storage applications.

Recent publications

Saad Zafar, Arpit Thomas, Soumyasri Nikhilesh Mahapatra, Naiwrit Karmodak, **Harpreet Singh Arora** and Bimlesh Lochab (2023), *Morphology-dependent enhancement of the electrochemical performance of CNF-guided tunable VS4 heterostructures for symmetric supercapacitors*, **Journal of Materials Chemistry A, 11, 21263-21271 (I.F: 11.51).**

A. Thomas, G. Perumal, D.B. Padmanaban, A. Kumar, R.K. Sharma, A. Ayyagari, Xiaolong Ma, B. Gwalani, **Harpreet S. Arora** (2023), *High Strain-rate Driven Nano-tubular Architecture in NiMn Alloy for Supercapacitor Electrodes*, **Chemical Engineering Journal,** 143008 (I.F. 16.7)

Ambrish Kumar, Arpit Thomas, Mayank Garg, Gopinath Perumal, **Harpreet S. Grewal** and Harpreet S. Arora (2021), *High-performance CuO@brass supercapacitor electrodes through surface activation, Royal Society of Chemistry*, **Journal of Materials Chemistry** A, 9,9327 (I.F. 14.51).

Arpit Thomas, Ambrish Kumar, G. Perumal, Ram K Sharma, Vignesh Manivasagam, Ketul Popat, Aditya Ayyagari, Anqi Yu, Shalini Tripathi, Edgar Buck, Bharat gwalani, Meha Bhogra, and **Harpreet S. Arora (2023),** *Oxygen-Vacancy Abundant Nano porous Ni/NiMnO3 / MnO2 @NiMn Electrodes with Ultrahigh Capacitance and Energy Density for Supercapacitors*, **ACS Appl. Mater. Interfaces,**15, 4, 5086–5098. (I.F. 10.38)

Arunesh Kumar, Arpit Thomas, and **Harpreet S. Arora** (2023), Deformation-Mediated Surface Activation of a Ni−Cu−Mn Ternary Alloy System for Energy Storage in Supercapacitors, **ACS, Energy & Fuels,** 37, 4720-4725 (I.F. 4.6)

A. Thomas, A. Rajeev, A. Kumar, G. Perumal, **Harpreet Arora** (2023), *Excellent Energy Storage and Electrochemical Performance of in-situ Grown Nano-porous CuO/MnO@ CuMn for Supercapacitors*, Accepted, **Ionics (I.F: 3)**

How do you think your work is creating a long-term impact on sustainability?

The distressing environmental concerns and climate change necessitate a paradigm shift from fossil fuels to renewable and clean energy sources, storage, and conversion systems. These issues have recently aroused tremendous research interest in developing facile and efficient strategies for a sustainable alternative, particularly green hydrogen, being a clean fuel with high energy density. Electrochemical water-splitting (EWS) is considered one of the cleanest and most eco-friendly techniques for hydrogen production. While noble-metal-based catalysts viz. Pt/C and RuO2/IrO2 are considered benchmark materials for green hydrogen generation through EWS; their scarcity and high cost are the limiting factors undermining their excellent electro-activity.

My research group at Shiv Nadar is working to develop non-noble metal-based efficient electro-catalysts with facile synthesis, low overpotential, and high stability. These techniques are scalable and can be utilized to develop large-scale electrodes for electrolyzers to generate green hydrogen with a high production rate. Thus, our research is aimed to significantly contribute towards reducing fossil fuel dependence, thereby strengthening the sustainable ecosystem.

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Shiv Nadar Institution of Eminence is fully committed to the UN Sustainable Development Goals (SDGs). We have embraced a four-pronged strategy for SDGs through **teaching, research, our core institutional practices, and partnerships.**

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