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Amir Waseem
Quaid-i-Azam University,
(Islamabad, Pakistan);
V.V. Zhylinski
Belarusian State Technological University,
(Minsk, Belarus)

THE NEW MATERIALS BASED ON MXENES FOR DEVELOPING OF SUSTAINABLE ENERGY

This text discusses the growing need for renewable energy sources in light of the depletion of fossil fuels and their negative environmental impact. It highlights hydrogen energy as a promising alternative due to its high efficiency and low emissions. The text also explores the role of MXenes, a class of 2D materials, in advancing energy storage and conversion technologies. MXenes are particularly useful in lithium-ion batteries and supercapacitors, offering superior performance in energy density, charge/discharge rates, and cycling stability. Additionally, MXenes are explored for their potential in hydrogen evolution reactions, contributing to sustainable energy solutions.

In contemporary society, a substantial quantity of energy is required to facilitate the operation of diverse industries, transportation systems and agricultural practices. Traditional energy sources, such as petroleum and coal, remain prevalent for the purposes of energy generation; however, these resources are non-renewable and contribute to various environmental challenges, including pollution and climate change. There exists an imperative for clean, renewable and sustainable energy sources in the current era. Renewable energy is defined as energy derived from resources that naturally replenish over time, thereby meeting energy demands without jeopardizing the needs of future generations, while also avoiding detrimental impacts on the environment [1]. A wide array of renewable energy sources is encompassed by sustainable energy, including hydroelectric power, biomass, geothermal energy, wind power, wave energy, solar energy, and hydrogen energy [1].

A prominent paradigm in sustainable energy is the hydrogen economy, wherein hydrogen gas is utilized to meet the electrical energy requirements of nations, thereby decreasing reliance on fossil fuels. The high efficiency and minimal pollutant emissions associated with hydrogen and fuel cells offer significant potential for diminishing greenhouse gas emissions across various applications. The abundance of hydrogen, primarily found in water, is substantial; nevertheless, it necessitates an efficient process for extraction via water splitting. The fundamental aspects of energy conversion and storage hinge upon charge transfer and mass diffusion [1].

The rational design of structures tailored for practical use is facilitated by investigating the relationships between the structural properties and functionalities of materials, along with comprehending charge transfer, mass diffusion, and the specific requirements of materials for specialized applications. Numerous inorganic functional materials, including innovative metals, oxides, sulfides, selenides, and their heterojunction nanomaterials with diverse morphologies, have been synthesized for high-performance energy-related devices. The rational design of materials and unique structural configurations (e.g., hollow, hierarchical, and heterojunction structures) has been shown to exhibit exceptional performance in photocatalytic water treatment, solar hydrogen evolution, solar cells, and energy storage applications (e.g., oxygen evolution reaction and oxygen reduction reaction electrocatalysts for fuel cells) [1].

A straightforward synthetic approach will be utilised to produce and exfoliate 2D materials (MXenes) and their composites for synergistic effects and a wide range of applications. Additionally, various MXene composites will be developed for applications in energy storage and enhancing supercapacitor performance [2].

The depletion of fossil fuels has heightened interest in renewable energy resources, with MXenes being used in energy storage applications. Lithium-ion batteries are characterized by their eco-friendliness, excellent cycling performance and high energy density, making them suitable for use in portable electronics. Graphite anodes exhibit limited energy storage capacity (330 mA h g^{-1}). In comparison, MXenes possess increased specific surface areas, electrical conductivity, lower circuit voltage and significantly reduced Ti_3C_2 diffusion barriers for Li-ions. Moreover, MXenes demonstrate superior gravimetric capacities relative to graphite. Monolayer MXenes exhibit superior capacity for Li ions compared to their multi-layered counterparts, thus monolayers are favoured. However, functional group terminations can heighten diffusion barriers, thereby exerting a negative influence on storage capacities. The removal of -OH groups enhances storage capacity, while -O terminations also contribute positively. M_2X compounds with light transition metals and -O terminations are optimal for anodes in lithium-ion batteries. Additionally, MXenes have the capacity to be incorporated into non-lithium-ion batteries through the intercalation of various metallic ions, including Na^+, K^+, Mg^{2+}, and Al^{3+} [2].

MXenes have been shown to be advantageous for supercapacitors due to their superior charge/discharge rates and prolonged cyclic stability in comparison to batteries. Multi-layered Ti_3C_2Tx exhibit varying behaviours in acidic versus basic electrolytes due to differences in charge-discharge mechanisms, with the HCl/LiF synthesis method being favoured as -O terminations enhance volumetric capacitance [3]. Acidic electrolyte conditions have been shown to further increase capacitance. Various strategies have been employed to mitigate aggregation, including vertically aligned liquid-crystallites, hydrogels, conductive particle decoration (e.g., NiO and Nb_2O_5), and interlayer spacers [4]. Notably, the Ti_3C_2Tx-polypyrrole nanocomposite demonstrates the highest reported volumetric capacitance to date [3]. Experimental findings of MXenes have also documented gravimetric and volumetric capacitances across different electrolytes. In energy conversion, for example, hydrogen evolution reactions, molecular hydrogen (i.e. carbon-free fuel) is produced by electrocatalysis. In the case of MXenes, the ideal Gibb's free energy can be achieved by adding transition metal adatoms for hydrogen adsorption [5].

In conclusion, the transition to renewable energy sources is essential to address the environmental challenges posed by traditional fossil fuels. Hydrogen energy, together with materials such as MXenes, offers promising solutions for sustainable energy production and storage. MXenes, with their unique properties, have exceptional potential to improve energy storage devices such as lithium-ion batteries and supercapacitors.

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