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Biomass as Both Feedstock and Functional Material for Hydrogen Production: A Dual Role in Sustainable Energy

ABSTRACT

Efficient hydrogen production from renewable resources requires catalytic routes capable of converting biomass derivatives and waste feedstocks into hydrogen-rich gas, as well as low-cost materials capable of supporting the downstream steps of conversion, storage, and carbon management. Biomass can contribute to both fronts, serving as a renewable feedstock to be catalytically upgraded into hydrogen-rich gas and as a precursor for the functional materials that enable the wider hydrogen chain. Both roles are addressed here within a single research framework on sustainable energy.

The work on the production side spans the full hydrogen chain, from feedstock conversion through gas upgrading to end-use. Catalytic steam reforming, gasification, and supercritical water gasification have been investigated for a range of renewable inputs, including model bio-oil oxygenates, ethanol, microalgae oil, and agricultural residues. Catalyst development has centered on transition metals such as Ni and Co, often combined with promoters such as La, on natural mineral and engineered oxide supports. Within this framework, acetic acid steam reforming has served as a particularly informative model reaction for bio-oil valorization, providing a benchmark against which the same catalyst-design principles can be evaluated across other feedstocks. Downstream of these reforming and gasification steps, complementary studies on CO2 capture by biomass-derived activated carbons and MOFs address gas purification, while work on alkaline water electrolysis, PEM fuel cell electrocatalysis, and electrochemical hydrogen storage closes the chain at the conversion and end-use stages.

In parallel, biomass is used not only as a feedstock but as a source of functional materials within hydrogen production and conversion systems. Recent work in this direction includes the development of biomass-derived composite membranes from banana peel, incorporated into a polysulfone matrix as a low-cost alternative to commercial Zirfon® for alkaline water electrolysis, where the bio-derived membranes showed improvement in ionic transport performance over the commercial reference. This direction extends biomass valorization beyond hydrogen generation, into the materials that make up the surrounding production and conversion infrastructure.

ABSTRACT

Taken together, these studies position biomass as a chemically diverse platform that supports both sides of the hydrogen chain, linking catalytic conversion of renewable feedstocks with the design of bio-derived functional materials for sustainable energy systems.

BIOGRAPHY

Prof. Dr. Nezihe Ayas is a distinguished academic and researcher in Chemical Engineering at Eskişehir Technical University, Türkiye. Her research interests encompass hydrogen energy, fuel cells, renewable energy, biomass conversion, biofuels, gasification, catalytic processes, and sustainable energy technologies. She has made significant contributions to scientific research through numerous publications and academic projects, particularly in the development of sustainable approaches for energy production and biomass valorization. Prof. Ayas is actively involved in postgraduate education and research, contributing to the advancement of innovative and environmentally sustainable chemical engineering technologies.