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Fabrication of Electrodes using High Surface Area 3D Graphene Substrates

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The development of sustainable and clean energy sources is essential to mitigate environmental issues arising from excessive energy consumption. Electrochemical water splitting via the hydrogen evolution reaction (HER) offers a promising method for hydrogen production due to its sustainability and environmental advantages. Although precious noble metals like platinum are renowned for their excellent electrocatalytic properties in HER, their high cost and scarcity hinder widespread application. Consequently, researchers have focused on identifying inexpensive, abundant, and highly efficient electrode materials. Several strategies have been proposed to enhance overall electrochemical performance, including the construction of porous structures, defect engineering, and morphology control [1]. Among these strategies, the synthesis of highly porous electrodes is considered particularly effective in improving overall electrode performance [3].

Graphene, a two-dimensional (2D) material composed of a single layer of carbon atoms, is often highlighted as a promising electrode material due to its high theoretical specific surface area and its ability to facilitate charge transfer along its 2D surface [2]. This study investigates the synthesis of a three-dimensional (3D) graphene structure that can be integrated with electro- and photocatalysts to serve as electrodes for hydrogen production through two different approaches.

The first approach involves creating 3D graphene foam via chemical vapor deposition (CVD) using a nickel foam template [3]. MoS_2, a 2D inorganic electrocatalyst, is then deposited onto this 3D graphene foam to form a heterostructure electrode [1]. Initial electrochemical trials indicate that the new graphene foam-MoS_2 heterostructure is highly stable and exhibits a significant electrochemical surface area and low overpotential. The second approach focuses on developing Ni-Cu alloy templates using the hydrogen bubble dynamic template method [4]. These Ni-Cu alloy templates facilitate the production of nearly transparent 3D graphene, which can serve as a substrate for depositing photocatalysts. SEM and Raman analysis confirm the presence of few-layer graphene, which can be used to develop a highly porous Graphene-MoS_2 heterostructure electrode.

Bibliography:

[1] Liu, Chunli, et al. "MoS2/graphene composites: Fabrication and electrochemical energy storage." Energy Storage Materials 33 (2020): 470-502.
[2] Oyedotun, Kabir O., and Ncholu Manyala. "Graphene foam–based electrochemical capacitors." Current Opinion in Electrochemistry 21 (2020): 125-131.
[3] Hussain, Sajjad, et al. "Facile and cost-effective growth of MoS2 on 3D porous graphene-coated Ni foam for robust and stable hydrogen evolution reaction." Journal of Alloys and Compounds 788 (2019): 267-276.
[4] Huang, Ming, et al. "CVD growth of porous graphene foam in film form." Matter 3.2 (2020): 487-497.