# $MOS_2$-BASED CATALYST FOR HYDROGEN PRODUCTION IN PEM ELECTROLYSIS

[1*]*Maria Aurora Mancuso*, *Stefania Siracusano*, *Fausta Giacobello, Veronica Cicciò, Alessandra Muscolino, Antonino Salvatore Aricò*
[1] CNR-ITAE, Salita Santa Lucia Sopra Contesse, 5, 98126, Messina
*Corresponding author e-mail: maria.mancuso@itae.cnr.it

**ABSTRACT**
Developing low-cost electrocatalysts is key to improving proton exchange membrane (PEM) water electrolysis for sustainable hydrogen production. In the research for alternative catalyst materials, molybdenum disulfide ($MoS_2$) has shown great potential for the hydrogen evolution reaction (HER). This study investigates $MoS_2$-based catalysts synthesized via a hydrothermal method, including an unsupported variant and two supported on Ketjenblack EC carbon (KB). Physico-chemical characterization was conducted using different techinques, while electrochemical performance was evaluated in a PEM single cell through polarization, electrochemical impedance spectroscopy (EIS) , and durability tests. The supported $MoS_2$ catalyst, incorporating KB during synthesis, exhibited superior performance with higher current densities, lower polarization resistance and higher durability, demonstrating its potential as a viable alternative to noble metal-based cathodes.

**Keywords:** PEM electrolyzer, non-Noble catalysts, $MoS_2$, Hydrogen, Proton Exchange Membrane

## 1. INTRODUCTION
The increasing global energy demand and the environmental impact of $CO_2$ emissions from fossil fuel combustion make the research for sustainable alternative energies crucial. Hydrogen is considered one of the most promising options, offering a more sustainable solution with a lower environmental impact in the context of modern energy consumption, and its combustion results exclusively in water [1]. Among the available technologies, proton exchange membrane (PEM) water electrolysis is distinguished by its efficiency and reliability, though the reliance on noble metal catalysts such as platinum and iridium limit its economic sustainability. In the context of today's scientific efforts to advance hydrogen production, there is a growing focus on developing non-precious catalysts to make water electrolysis more accessible and cost-effective [2].
Molybdenum disulfide ($MoS_2$) has emerged as a promising alternative due to its abundance and favorable catalytic properties, offering a viable pathway for sustainable hydrogen production.

## 2. MATERIALS AND METHODS

### *2.1. Catalyst preparation*
Three $MoS_2$ catalysts were synthesized for cathode applications using a suitable and low-cost hydrothermal method: one unsupported and two supported on Ketjenblack EC carbon (KB). The difference between the two supported catalysts lies in the preparation: one was mechanically mixed with KB (supported-1), while in the other, KB was incorporated with the precursors (supported-2) to enhance catalytic efficiency while reducing the metal catalyst loading.

### *2.2. Physico-chemical characterization*
To investigate the physico-chemical properties of the synthesized electrocatalysts, various characterization techniques were employed. X-ray Diffraction (XRD) was used to analyze the crystal structure and to evaluate crystallite size, while X-ray Fluorescence (XRF) was performed to determine the elemental composition of the catalysts. Transmission Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy (TEM-EDX) allowed to know the powders morphology, structure, and elemental distribution. Additionally, Thermogravimetric Analysis (TGA) was conducted to monitor mass variations as a function of temperature under controlled atmospheric conditions.

### *2.3. PEM electrolyser setup*
The electrochemical performances of the synthesized $MoS_2$ and $MoS_2$/C catalysts were investigated in a single PEM cell with a 5 cm² active area by polarization corves and electrochemical impedance spectroscopy (EIS) in a range of temperature between ambient to 90°C; galvanostatic durability tests were performed at an operating temperature of 80°C. The cells were assembled using a commercial $IrO_2$ as the anode and the three synthesized $MoS_2$ catalysts as the cathodes. A NAFION 212 membrane was placed between the electrodes to complete the PEM-based MEA assembly.

## 3. RESULTS AND DISCUSSION
The comparative analysis of the three catalysts revealed that the supported-2 $MoS_2$ catalyst exhibited superior electrochemical performance. In polarization measurements, it achieved higher current densities at lower voltages compared to both the unsupported and supported-1. Electrochemical impedance spectroscopy (EIS) further confirmed

lower polarization resistance at different voltage values, which suggests enhanced charge transfer efficiency; additionally, galvanostatic durability showed greater stability.
These findings confirmed the supported-2 $MoS_2$ as the most operative cathode catalyst for hydrogen evolution reaction in PEM electrolisis.

## 4. CONCLUSIONS

In this work is reported a screening of catalysts based on $MoS_2$ and $MoS_2$/C for hydrogen evolution reaction (HER) in acid environment. Non-CRM (non critical raw material) catalysts were synthetized by hydrothermal processes and characterized by physico chemical analyses, as XRD, XRF, TGA and TEM. The electrochemical characterization was carried out in terms of polarization curve, EIS at different potential value and galvanostatic durability test. The electrochemical evaluation of $MoS_2$ and $MoS_2$/C as cathodes in a PEM single cell revealed improved performance and stability for the supported $MoS_2$ catalysts, particularly for the one incorporating Ketjenblack EC carbon in the initial step with precursors.

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