Towards a new generation of electrocatalysts: electrospinning of bio-waste

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Highlights

- Deployment of Fuel Cells requires advancements in cost optimization and performance.
- Developing new, highly active, and cost-effective catalysts is essential.
- Electrospinning is employed to produce nanomaterials with high porosity and specific surface area.
- Lignin is a renewable and cost-effective alternative for catalytic materials.

1. Introduction

Hydrogen is highly interesting as a key player in the energy transition as it is a clean, sustainable, and versatile alternative energy vector suitable for various applications.
Indeed, hydrogen contains a high level of chemical energy that can be suitably converted into electrical energy; this is where fuel cells (FCs) come into play.
Among various technologies, Proton Exchange Membrane Fuel Cells (PEMFCs) devices convert the chemical energy of hydrogen directly into electrical energy with a much higher efficiency than conventional power generation sources, producing only water as byproduct. However, the large-scale deployment of FCs requires further progress in terms of cost optimization, performance, and hydrogen infrastructure. The economic aspect is mainly related to the large amounts of critical and expensive metals needed to overcome the overpotential required to operate the cell, especially for the reactions with oxygen, as these have the highest values of overpotential and of sluggish kinetics. To achieve high efficiency, the catalysts must have high specific surface area and porosity to utilize the full potential of the active phase. In addition, in order to reach high activity at low loading, metal dispersion should be high and homogeneous.
Among all the techniques available for designing and developing catalysts, electrospinning is an emerging technique allowing to produce materials featuring the above-mentioned properties [1].
Lignin, a complex biopolymer and biowaste from lignocellulosic biomass, has been selected as a renewable and cost-effective alternative for the production of catalytic materials using a regenerative approach. Lignin is of fundamental importance as it is rich in phenolic and polyphenolic groups, which are crucial for the complexation of metals such as platinum and for its reduction [2].
Therefore, in this work electrospinning of lignin will be exploit as a method for producing new profitable catalysts for FCs application featuring high porosity, high specific surface area and wide and homogeneous dispersion of the metal phase.

2. Methods

The fibers are obtained starting from a lignin solution into green solvents such as water and ethanol. The solution is then subjected to the process of electrospinning, an electrohydrodynamic process that produces micro- or nano-scale fibers using electrohydrodynamic forces.
Scanning electron microscopy (SEM) is used to carry out a morphological analysis of the fibers which, in conjunction with energy dispersion spectrometry (EDS), enables an assessment of the elemental composition of the fibers and the distribution of platinum on the fibers. By the means of BET measurements, it is possible to evaluate the specific surface area of the fibers and porosity. The presence of crystalline phases due to the presence of the active metal phase is confirmed by X-ray diffraction (XRD) analysis.

To evaluate the electrochemical performance of the catalyst and its stability, impedances will be measured by electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV) and polarization curve measurement.

3. Results and discussion

The morphology of electrospun fibers was evaluated by SEM Analysis. Figure 1a shows SEM images of fibers with an average diameter about 791 ± 217 nm. Figure 1b shows the EDX image of the same fiber, indicating a homogeneous and wide dispersion on the platinum in the fibers.

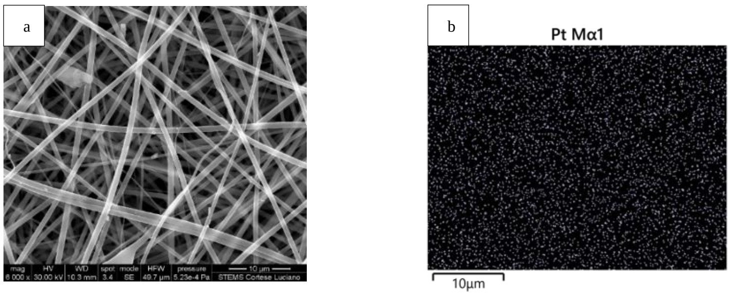

Figure 1. SEM image of lignin/platinum fiber (a) and the respective EDX image indicating the platinum dispersion (b).

This result suggests that the organic matrix can complex with platinum ions, bringing effectively and homogeneously the metal into the mat. This result is mainly due to the phenolic groups contained in lignin chemical structure. The presence of platinum is also confirmed by the XRD spectrum of the fiber, which displays the platinum patterns, as it can be seen in the figure 2.

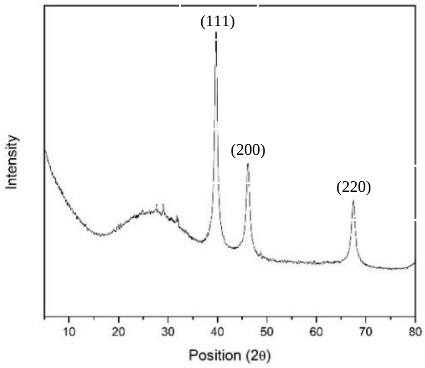

Figure 2. X-ray diffraction pattern of lignin supported platinum.

BET analysis shows that the fibers have very high specific surface area of 560 m^2/g, with the presence of micropores and mesopores within the structure.

4. Conclusions

PEMFC represents a key technology for the energy transitions towards carbon-free fuels since allows the exploitation of the potential of hydrogen as an energy vector. Yet, PEMFC implementation is highly limited by the cost and availability of the highly active catalyst, such as platinum. In this context, this project has developed lignin derived carbon fibers supporting Pt by means of the electrospinning technique for fuel cell applications. The combination of electrospinning technique, which confers to the fiber high surface area, as well as high porosity, and the chemical structure of lignin, are key features for a high and homogeneous dispersion of the metal, and therefore allows lower loading of platinum.

References

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Keywords

PEMFC; Hydrogen; Electrospinning; Lignin;